Appendices

Appendix A

Clear Creek Aquatic Habitat Assessment and Fish Distribution and Relative Abundance Surveys Sampling Framework

TECHNICAL MEMORANDUM ◦ MAY 2015

Clear Creek Aquatic Habitat Assessment and Fish Distribution and Relative Abundance Surveys Sampling Framework

P R E P A R E D   F O R

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P R E P A R E D   B Y

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Stillwater staff conducting stream habitat and fish population monitoring surveys in the McKenzie and North Umpqua river basins, Oregon

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1 INTRODUCTION

The objective of the Selway-Middle Fork Collaborative Forest Landscape Restoration Program (CFLRP) ecological monitoring activities is to document the degree to which various restoration treatments within the project area achieve their ecological and watershed health objectives.

The specific objective of the Aquatic Habitat Condition Assessment and Fish Population Monitoring project is to provide an inventory of habitat conditions, establish a baseline for impact analyses, and to document fish distribution and relative abundance in the Clear Creek watershed on the Nez Perce-Clearwater National Forest near Kooskia, Idaho. Results from the assessment will serve as a reference point for comparison with future surveys to evaluate habitat conditions and processes, water quality parameters, and population changes over time as a result of resource management in the basin. Of particular importance is the current spatial distribution and relative abundance of salmonid species in the basin. The quality, quantity, and distribution of steelhead and salmon spawning and rearing habitat, and the existence of upstream migration barriers will inform resource management decisions within the watershed.

The specific project goals include:

- Describe current stream channel and fish habitat conditions
- Identify potentially suitable salmon and steelhead spawning habitat
- Determine spatial distribution and relative abundance of salmonids
- Identify and evaluate potential barriers to fish migration
- Establish baseline datasets for determining impacts to aquatic habitat that can be attributed to the implementation of land management activities
- Establish and monument 2 permanent monitoring stations for the evaluation of potential changes to the physical habitat (e.g., spawning gravels), the physical processes (e.g., channel aggradation/degradation), and relevant water quality parameters (e.g., stream temperature)

The sampling framework described here has been developed to guide fish distribution and aquatic habitat surveys and ensure the data collected will be sufficient to characterize habitat conditions and relative fish abundance, while implementing an efficient approach with available resources. The sampling framework defines functional channel units (habitat units and reaches) and describes the scales at which data will be collected. The sampling framework relies on a hierarchical approach to dividing the channel network into function units at varying scales. The Clear Creek assessment will focus primarily on two scales, the habitat unit scale and the reach scale. The basin scale is also of interest for making comparisons with conditions in other locations, although not a primary focus of this effort. Within the Clear Creek basin, this effort will focus on priority streams within the study area (a subset of the Clear Creek basin) as identified by the CBC (Figure 1).

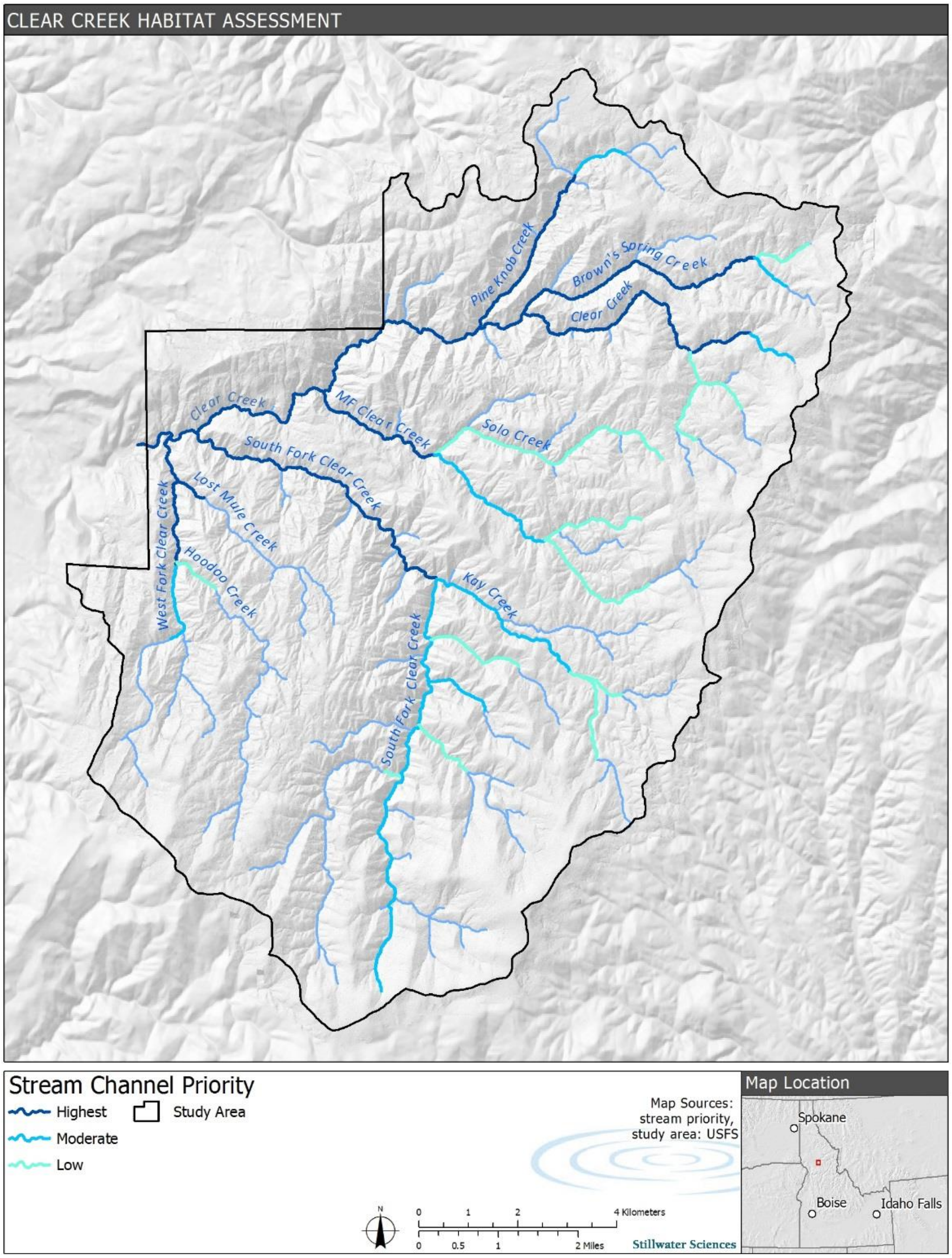


Figure 1. Priority stream designations in the Clear Creek study area.

Habitat units such as pools and riffles will be characterized in the field for all stream reaches surveyed, and are the smallest functional channel unit that will be used in the assessment. Habitat surveys will classify individual habitat units by type based on geomorphic characteristics, and describe physical habitat conditions within each habitat unit. Habitat unit scale sampling is described in Section 4. The detailed protocol for characterizing habitat units is described in the Field Protocol Technical Memorandum (Stillwater Sciences, in-prep[1]).

Fish distribution and relative abundance sampling are conducted at the habitat unit scale with sampling considerations at the reach scale. These surveys will employ a subsampling approach described in more detail in Section 5.

Reach identification for the Clear Creek assessment employs and process-based channel classification approach that is described in more detail in Section 2. Reach-scale measurements are intended to characterize channel and riparian conditions that influence aquatic habitat at scales larger than the habitat unit, such as channel geometry and riparian conditions (e.g., shade, terrestrial inputs) (Section 3).

The Clear Creek assessment will also include sampling at two long-term monitoring stations. Selecting the location of these sites, and the data collected at each site, is not specifically considered within the sampling framework described in this document. There are, however, sampling considerations associated with the long-term monitoring stations that warrant discussion and will be presented in Section 6. Other sampling considerations will be described in Section 7.

2 CHANNEL CLASSIFICATION/REACH IDENTIFICATION

Stratifying the channel network into functional reaches, provides a valuable structure to guide field sampling and data interpretation at appropriate scales. The reach concept is that channel segments having similar controlling conditions and experiencing similar influences on the landscape will, on average, function similarly and provide similar habitat conditions for fish and aquatic species. In addition, reaches of the same type are expected to respond similarly to similar types and magnitude of disturbance. Underlying conditions that control channel form and function include such factors as climate, elevation, geology, vegetation, channel slope, channel size, and channel constraint. Basin topography (e.g., digital elevation model or DEM) and the stream channel network forms the foundation of the spatial database, and provides a spatially-explicit framework for documenting channel and habitat conditions at various scales using geographic information systems (GIS).

We used a DEM for the Clear Creek study area (provided by the USDA Forest Service, Nez Perce National Forest) to generate a stream channel network using GIS. The study area and channel network was then attributed with controlling conditions intended to describe channel form and function for each reach within the stratification framework. For the Clear Creek assessment, channel gradient and drainage area were the primary attributes used to stratify the channel network into functional process-based reaches (or subreaches) based on concepts described by Montgomery and Buffington (1998[2]). The stream channel network was generated for high, medium, and low priority channels (Figure 1).

Drainage area was generated from the DEM and attributed to the channel network within GIS. Drainage area thresholds are intended to differentiate between channels of varying size and

[1] Stillwater Sciences. In-prep. Clear Creek Aquatic Habitat Condition Assessment and Fish Population Monitoring Field Sampling Protocol. Prepared by Stillwater Sciences for the Clearwater Basin Collaborative.

[2] Montgomery, D. R., and J. M. Buffington. 1998. Channel processes, classification, and response. Pages 13–42 *in* R. J. Naiman and R. E. Bilby, editors. River ecology and management. Springer-Verlag, New York.

position in the channel network (e.g., stream order). A range of potential drainage area thresholds were evaluated and the following four categories were selected to characterize relative differences in size at an appropriate scale for this assessment, <5 km^2, 5–25 km^2, 25–100 km^2, >100 km^2) (Figure 2).

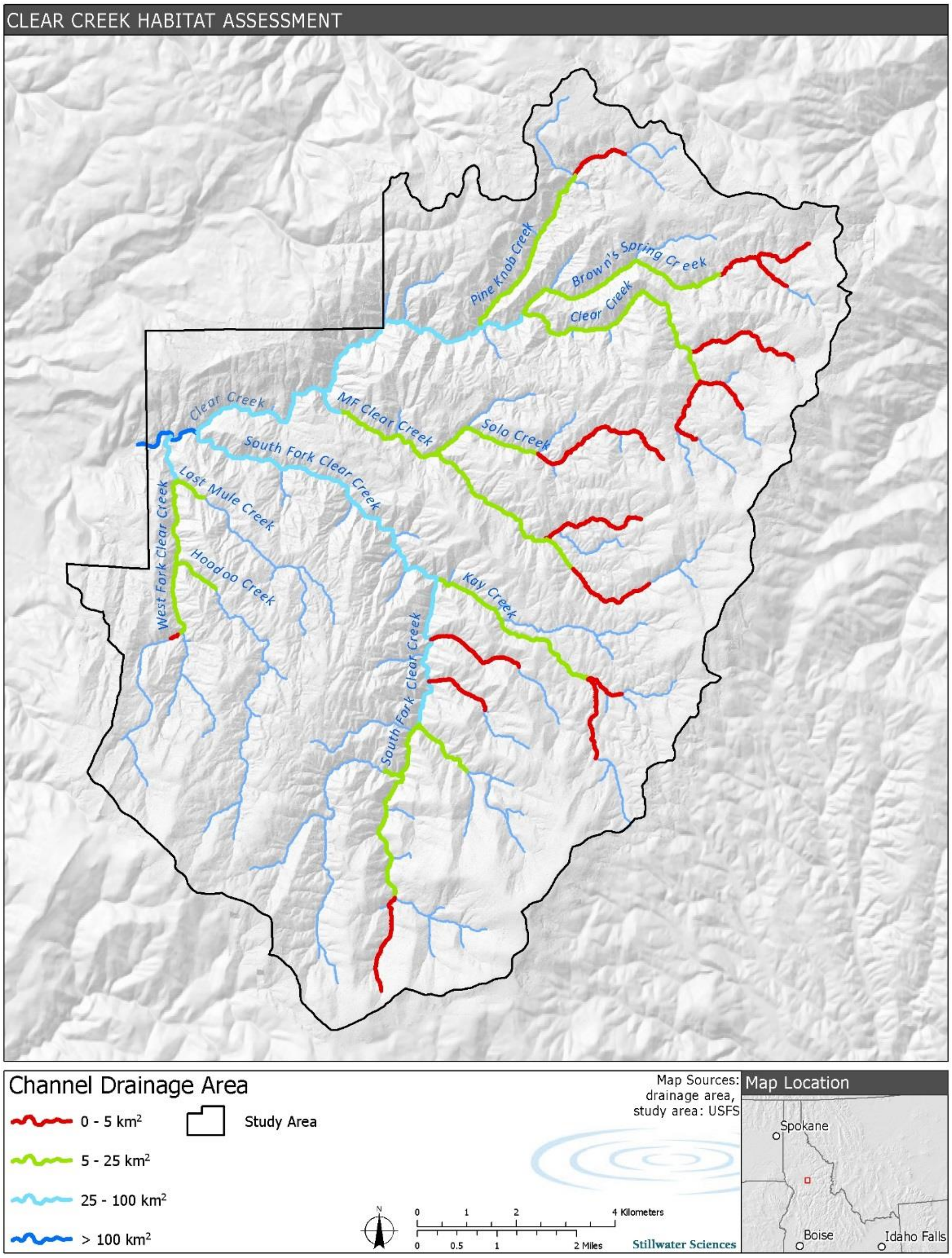


Figure 2. Contributing drainage area within priority streams.

Ten-meter elevation contours, also generated with the DEM, were used to calculate channel gradient by intersecting contours with the channel network using GIS. Channel gradient categories follow those described by Montgomery and Buffington (1998), and include 0–1%, 1–4%, 4–8%, 8–20%, and >20% (Figure 3). These gradient categories relate to channel bed morphologies (i.e., pool-riffle, plane-bed/forced pool-riffle, step-pool, cascade) sediment characteristics and response potential, and also correlate strongly with species habitat suitability and preferences (e.g., Chinook are typically found in reaches with gradients <4%, whereas steelhead may utilize reaches having an average gradient of 8% or higher).

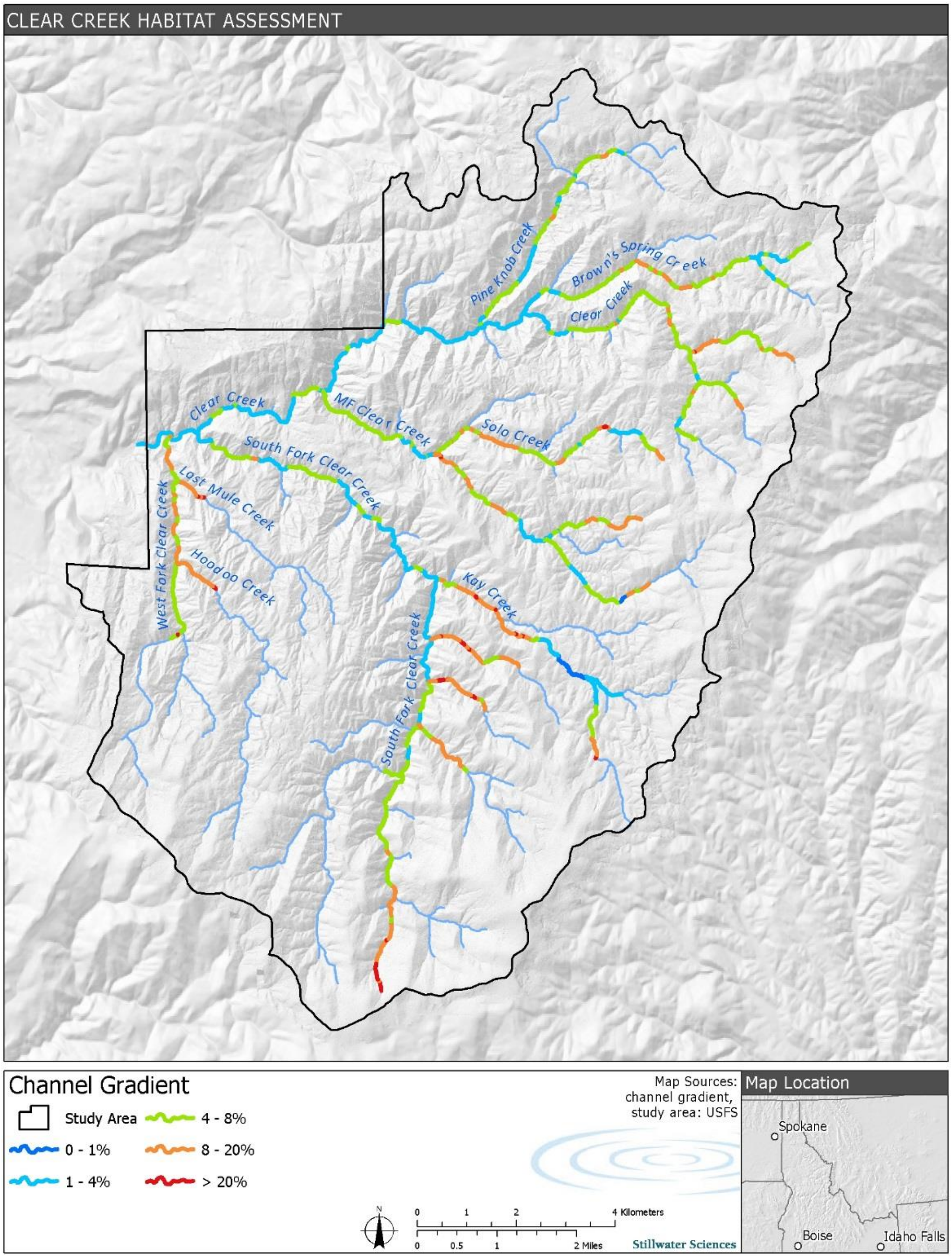


Figure 3. Channel gradient within priority stream reaches.

Geologic mapping indicates a dissected mosaic of plutonic, volcanic, and sedimentary rocks distributed throughout the basin with only a few small stream segments having subbasins contained within a single geologic type (Figure 4). Geologic influences on priority channels in the study area are varied and diverse, and don't easily lend themselves to identifying clear influences on channel conditions at the reach scale. A more detailed evaluation of these factors was not within the scope of this project, and geology was not used to further stratify the channel network as a result.

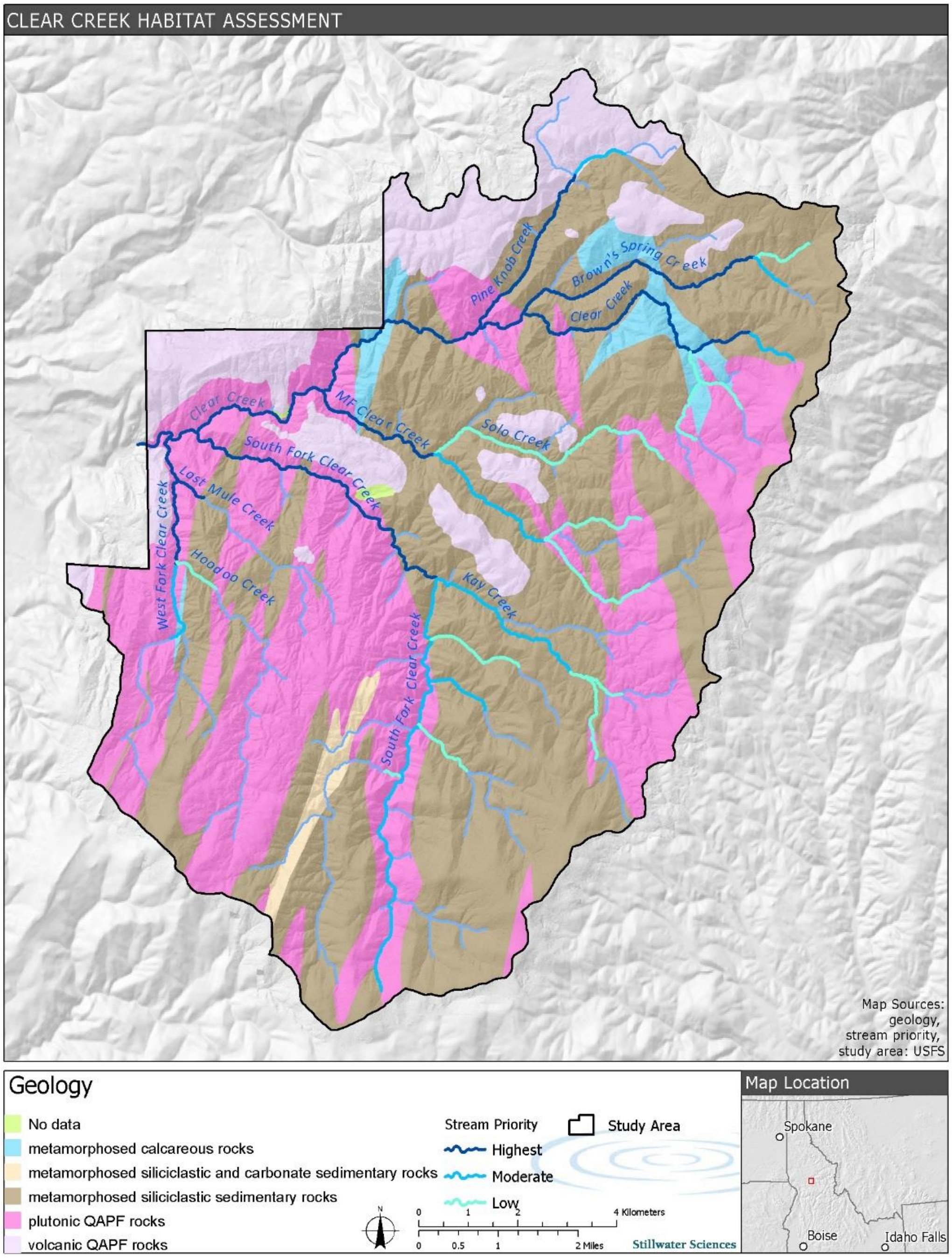


Figure 4. Geology within the Clear Creek study area.

Vegetation mapping integrates soils, geology, climate, elevation, topography, aspect, and other factors. Within the study area, vegetation is dominated by coniferous forest, with nearly all areas dominated by Grand fir (Figure 5). Vegetation was generally considered similar across the study area, or where dissimilar would be captured within the existing stratification approach, and was not used to further stratify the channel network. Conditions such as climate and elevation were considered similar throughout the study area, as was channel confinement, based on an assessment of aerial imagery (Google Earth) and DEM topography.

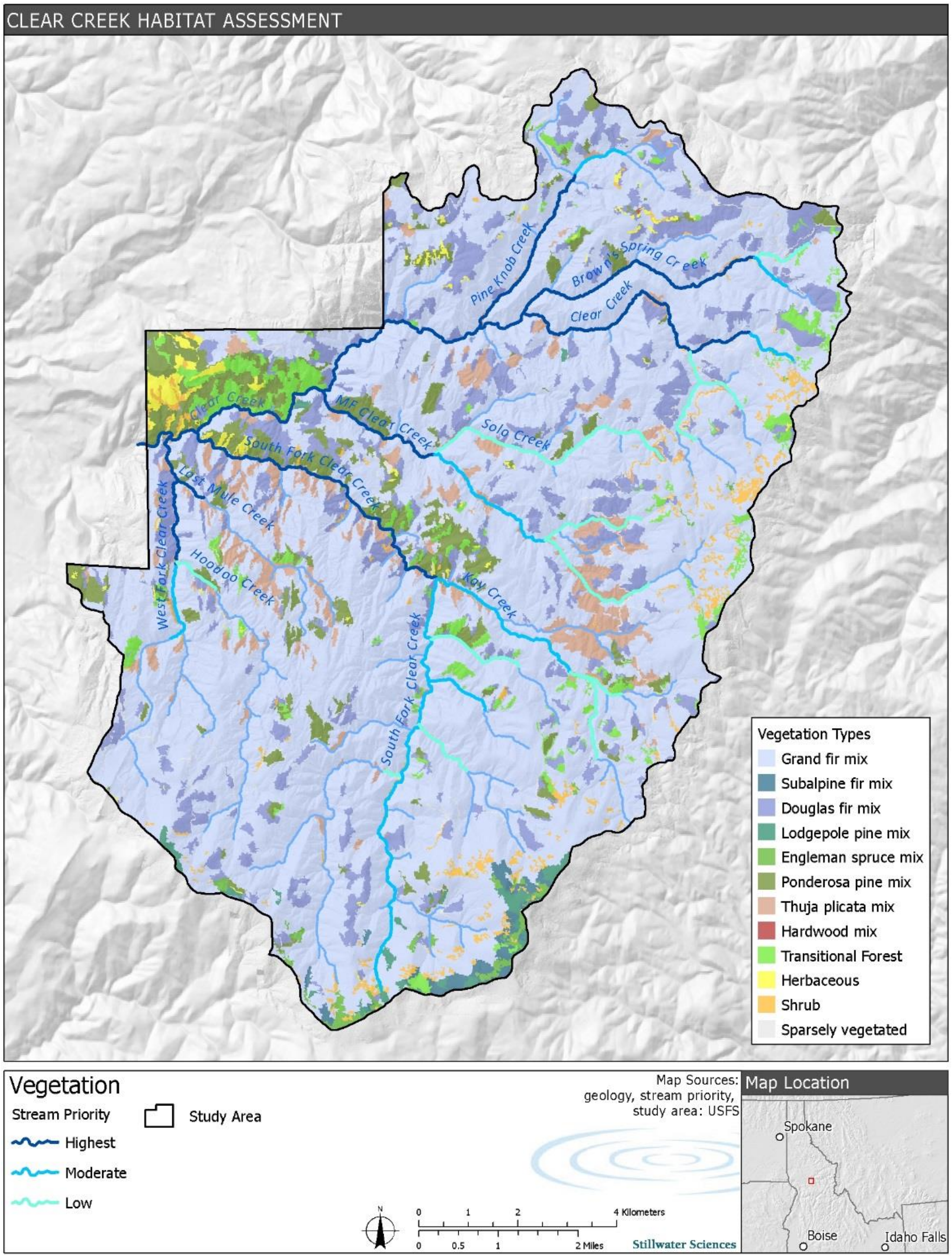


Figure 5. Vegetation cover types in the Clear Creek study area.

Study reaches were defined by categorizing channel segments by the channel gradient and drainage area categories described above. The channel classification framework theoretically results in 20 potentially unique channel type categories, although, some channel types are rare or nonresistant under most settings. A minimum reach length guideline was also used to ensure reaches were of reasonable length to warrant reach-scale characterization measurements. The guideline used included a minimum reach length of 150 m or about fifty times the average bankfull channel width, estimated for each of the four drainage area categories, which ever was greater. Reach classification was performed for the 27 miles of high priority streams.
In a few cases, preliminary reach designations oscillated between two gradient categories over a relatively short distance and resulted in a series of relatively short reach breaks. In these cases, detailed maps of channel gradient were reviewed to determine whether gradient changed substantially, and changes in channel form were likely, or whether channel gradient was generally similar (e.g., changes were an artifact of being near a gradient category threshold), and substantial changes in channel form were not likely. In about six cases, short segments were subsumed within larger reaches.

For high priority streams in the Clear Creek study area, 52 reaches were identified representing eleven channel types (Table 1, Figure 6). Individual reach lengths range from 165 to 2,805 meters (Table 2).

Table 1. Cumulative reach length by channel type for high priority streams in the Clear Creek study area.

Channel gradient (%)	Drainage area (km^2)			
	<5	**5–25**	**25–100**	**>100**
0–1	0	0	0	0
1–4	165	4,005	11,979	1,758
4–8	1,622	12,564	6,560	0
8–20	696	3,597	525	0
Over 20	0	176	0	0

These pre-identified reaches will be the basis for data collection and analysis. However, the exact boundaries of the reaches will be identified in the field based on observed characteristics, and will coincide with a habitat unit boundary.

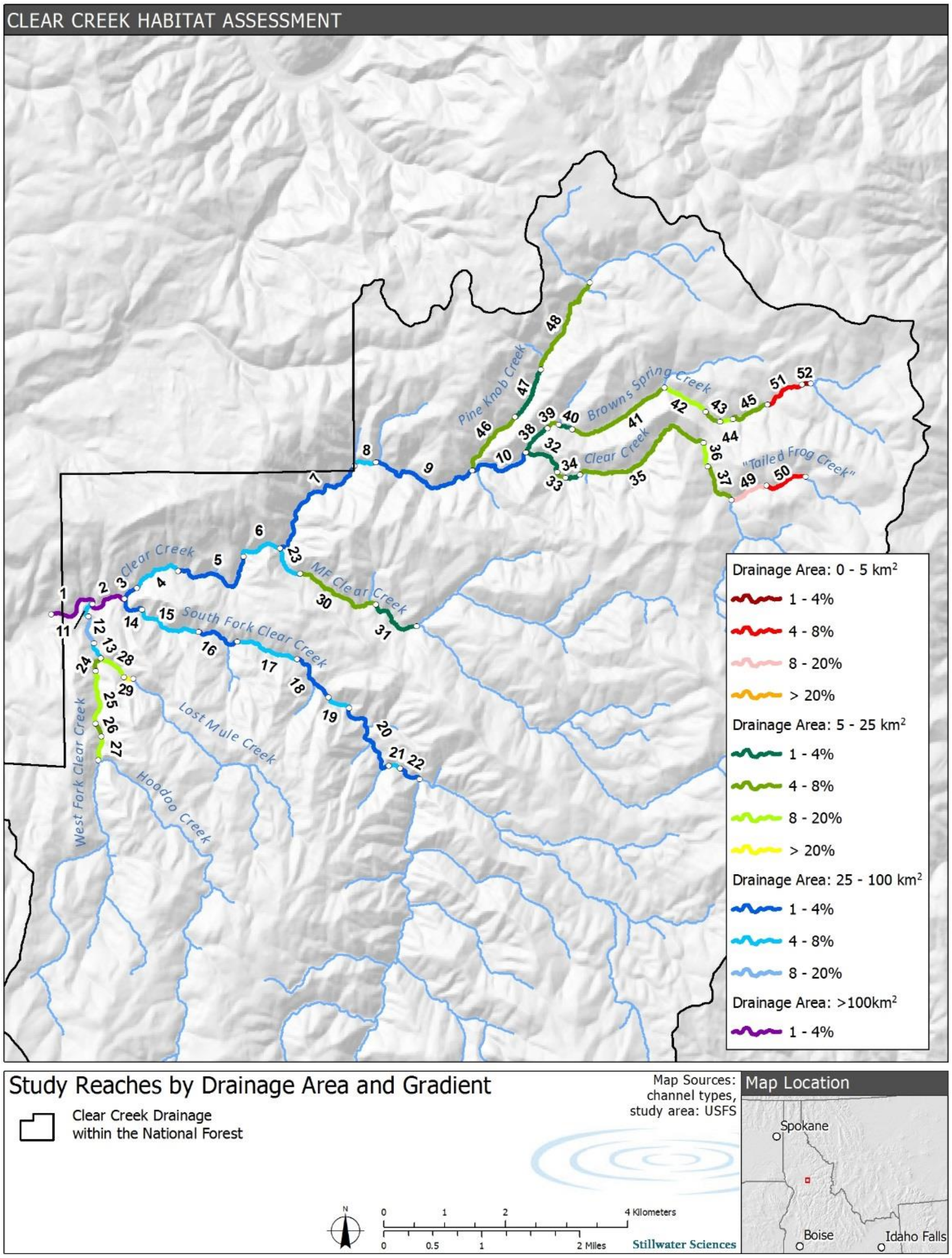


Figure 6. Distribution of reaches and unique reach identification for high priority streams in the Clear Creek study area.

Table 2. Reach identification, channel type characteristics, and length for high priority streams in the Clear Creek study area.

Reach ID	Drainage area (km^2)	Gradient (%)	Length (m)
1	Over 100	1–4	1,026
2	Over 100	1-4	733
3	25–100	1–4	294
4	25–100	4–8	971
5	25–100	1–4	1,696
6	25–100	4–8	821
7	25–100	1–4	2,321
8	25–100	4–8	447
9	25–100	1–4	2,132
10	25–100	1–4	1,233
11	25–100	4–8	318
12	25–100	8–20	525
13	25–100	4–8	302
14	25–100	1–4	479
15	25–100	4–8	1,202
16	25–100	1–4	820
17	25–100	4–8	1,158
18	25–100	1–4	964
19	25–100	4–8	459
20	25–100	1–4	1,584
21	25–100	4–8	221
22	25–100	1–4	456
23	25–100	4–8	661
24	5–25	4–8	288
25	5–25	8–20	1,015
26	5–25	4–8	261
27	5–25	8–20	454
28	5–25	8–20	565
29	5–25	Over 20	176
30	5–25	4–8	1,655
31	5–25	1–4	1,023
32	5–25	1–4	785
33	5–25	4–8	191
34	5–25	1–4	281
35	5–25	4–8	2,805
36	5–25	8–20	451
37	5–25	4–8	847
38	5–25	1–4	604
39	5–25	4–8	246
40	5–25	1–4	271
41	5–25	4–8	1,945
42	5–25	8–20	870
43	5–25	4–8	329
44	5–25	8–20	242
45	5–25	4–8	743
46	5–25	4–8	1,319
47	5–25	1–4	1,040
48	5–25	4–8	1,935
49	0–5	8–20	696
50	0–5	4–8	811
51	0–5	4–8	812
52	0–5	1–4	165
Total length			**43,648**

3 REACH-SCALE SAMPLING

Data collected at the reach scale includes channel form, constraining features, and riparian vegetation characterization. Reach-scale characteristics will be assessed at least one time per reach. In reaches greater than 1,000 m, multiple reach-scale characteristics will be measured. Longer reaches will be divided into approximately even-length segments between 500–1,000 meters using GIS. For example, a 1,700-m reach would have three 566-m segments, each having reach-scale measurements collected. When practical, field crews will attempt to select locations for reach-scale measurements within the middle 50% of a segment. The location of measurements for reach-scale characteristics will be coincident whenever possible, such that one transect location would be selected for measuring channel form, constraining features, and riparian vegetation characteristics. Transects will be placed in riffle habitats, and transect locations should be considered by the field crew as generally representative of reach-scale conditions. Locations with strong channel planform or valley curvature will be avoided, unless typical of the character of the reach or segment. The transect location within the riffle will be selected based on professional judgment to facilitate measurements and avoid anomalous or unique characteristics. Details of the reach-scale field measurements are described in the Field Protocol Technical Memorandum.

4 HABITAT UNIT-SCALE SAMPLING

Habitat unit-scale sampling will focus on classifying habitat unit types (riffle, pool, cascade, etc.) and characterizing aquatic habitat conditions within each identified habitat unit (width, depth, presence of large woody debris). Habitat units are defined based on geomorphic characteristics associated with width, depth, flow, substrate, and slope, among others. The frequency of different habitat types, as well as conditions within and between unit types, is expected to vary by reach type. Habitat types and characteristics can also be responsive to local conditions and/or disturbance. Habitat unit characteristics will be evaluated at multiple scales (e.g., unit type, reach type, subbasin) and summarized in the final technical report. Details of the habitat unit-scale field measurements are described in the Field Protocol Technical Memorandum. Sampling considerations specific to fish distribution and relative abundance are described below.

5 FISH DISTRIBUTION AND RELATIVE ABUNDANCE SAMPLING

Fish distribution and relative abundance sampling is intended to describe the distribution of resident and anadromous salmonid populations for priority streams in the study area. Fish distribution and relative abundance will be evaluated using snorkel methods. Sampling for fish distribution and relative abundance will be conducted concurrently with habitat and reach-scale sampling.

In general, fish distribution sampling and relative abundance sampling is similar and overlaps substantially, although each has slightly different objectives that require consideration at the basin, reach, and habitat unit scales to implement efficiently and effectively. Fish distribution and relative abundance sampling employ the same snorkel methods, although the sampling frequency is adjusted to meet specific objectives.

Fish distribution and relative abundance sampling will be evaluated exclusively within pool habitats. Pool habitats generally provide conditions that are suitable for using snorkel methods where fish residing in the habitat unit can be observed and enumerated with reasonable accuracy. This is in contrast to a riffle habitat, where conditions make it difficult for snorkelers to sample effectively and observe fish. Pool habitats typically also have relatively high utilization by all age classes of salmonids. Sampling of pool habitat only (and excluding fast water habitats) is a standard protocol used in systematic snorkel surveys throughout Oregon, and are specified in the ODFW Aquatic Inventory Methods for Stream Habitat Surveys. Excluding fast-water habitats may reduce the detection probability of some species that tend to utilize fast water habitat preferentially during certain periods (e.g., foraging, seasonally). However, surveys focusing exclusively on pools should provide results that are representative of spatial trends in distribution and abundance of fish populations.

Systematic snorkel surveys will be conducted during daylight hours. While the detection frequency of fish using snorkel methods can vary between day and night sampling (especially for some species such as bull trout), with night surveys more likely to detect rare or cryptic species, effort, safety, and logistical constraints prevent a systematic night snorkeling protocol. Instead, if possible, a few pools will be opportunistically snorkeled at night (for instance if pools are present in the immediate vicinity at the end of the work day) and the results will be reported separately.

The snorkel surveys are designed to describe the relative abundance of resident and anadromous fish populations, both by species and age class. Relative abundance sampling is not intended to estimate population abundance, but rather to provide a general understanding of relative differences in fish abundance between reaches and subbasins to ascertain where habitat conditions support relatively abundant populations, and where habitat conditions are less productive and support populations that are relatively less abundant.

A systematic random sampling approach will be employed at the reach-scale to determine which habitat units are sampled. Single-pass snorkel methods (Phase I) will be performed in every fifth pool habitat unit encountered within each reach. The first pool to be sampled within a reach will be selected at random by generating a random number between 1 and 5. Thereafter, every fifth pool in the reach will be sampled using single-pass methods. Three-pass snorkel methods (Phase II) will be performed in every fifth pool of the pools sampled during Phase I. The three-pass Phase II sampling will provide an estimate of diver observation probability. Phase II sampling is not reach-specific.

When encountering a potential barrier to anadromous fish distribution (where juvenile anadromous fish have been observed in the reach immediately downstream of the potential barrier) the first pool upstream of the potential barrier will be surveyed using single pass snorkel methods. If sampling the first pool upstream of the barrier does not indicate presence of anadromous fish, the third and fifth subsequent pools will be sampled to lend evidence to the absence of anadromous fish above the barrier. If anadromous fish are observed upstream of a potential barrier, sampling would continue in every fifth pool as described above, starting with the first pool upstream of the barrier where anadromous fish were observed. If no anadromous fish are observed in the first, third, and fifth pools sampled, and resident fish are observed in one or more of the pools, fish distribution and abundance sampling would continue for resident fish in every fifth pool as described above. In the absence of potential barriers to anadromous fish, anadromous fish distribution will be identified from the pools sampled.

When encountering a potential barrier to resident salmonid distribution (upstream of a documented anadromous barrier, where resident salmonids have been observed in one or more reaches immediately downstream of a potential barrier) the first pool upstream of the potential barrier will be sampled using single-pass snorkel methods. If sampling the first pool upstream of the barrier does not indicate fish presence, the third pool will be sampled, followed by the fifth pool if no fish are observed in the third pool. If no fish are observed in first three pools sampled upstream of the barrier, fish distribution and abundance sampling will be discontinued. If resident fish are observed upstream of the potential barrier, sampling would continue in every fifth pool as described previously, starting with the first pool upstream of the potential barrier where fish were observed. In the absence of obstacles identified as potential barriers to resident fish, fish distribution and abundance sampling will continue until fish are not observed in three consecutive pool habitat units sampled.

6 LONG-TERM MONITORING STATION SAMPLING

Two intensive monitoring stations will be established, in addition to the three currently established, at specified locations. Given that the Forest has already developed a standardized protocol for these intensive monitoring locations, sampling procedures will be consistent with the methods already being conducted. At each station the variables evaluated will include stream channel physiography, water temperature, stream bed surface substrate, cobble embeddedness, and fish population sampling according to the procedures specified by the CBC, and detailed in the Field Protocol Technical Memorandum.

Within the two newly established monitoring stations, we recommend that each station include at least one pool habitat unit, and that the pool habitat unit boundary be coincident with either the upstream or downstream monitoring station boundary. This will allow fish populations in the pool to be sampled separately from populations in the rest of the monitoring station to provide additional information on diver observation efficiency. The pools, would be snorkeled (one-pass) first, and would also be sampled with depletion electrofishing, separately from the rest of the monitoring station.

7 OTHER DATA AND CONSIDERATIONS

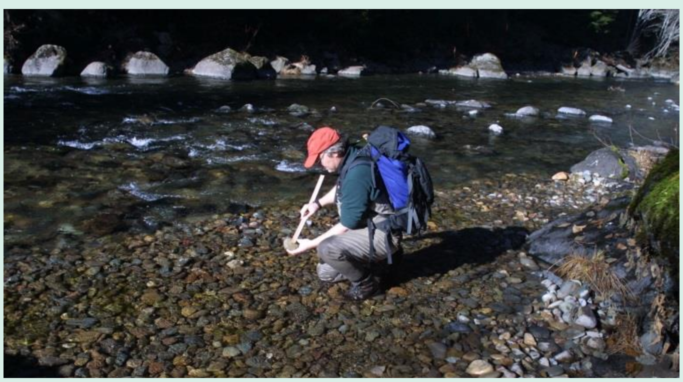
In addition to topography, stream channels, and reach designations, GIS layers such as roads, trails, and land ownership will be used to inform development of an efficient plan for implementing field surveys. Stillwater will work with the CBC and others to identify locations to access the stream, and key features such as bedrock falls that will inform field crews and assist in planning. Spatial information will also assist with tracking progress through the field implementation period.

Appendix B

Clear Creek Aquatic Habitat Condition Assessment and Fish Population Monitoring Field Sampling Protocol

TECHNICAL MEMORANDUM ◦ UPDATED DECEMBER 2015

Clear Creek Aquatic Habitat Condition Assessment and Fish Population Monitoring Field Sampling Protocol



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Cover photos: Stillwater staff conducting habitat assessments of the Umpqua River.

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Tables

Figures

1 INTRODUCTION

The objective of the Aquatic Habitat Condition Assessment and Fish Population Monitoring project is to provide an inventory of habitat conditions, establish a baseline for impact analyses, and to document fish distribution and relative abundance in the Clear Creek watershed on the Nez Perce-Clearwater National Forest near Kooskia, Idaho. Results from the assessment will serve as a reference point for comparison with future surveys to evaluate habitat conditions and processes, water quality parameters, and population changes over time as a result of resource management in the basin. Of particular importance is the current spatial distribution and relative abundance of salmonid species in the basin. The location of quality habitat for steelhead and salmon spawning and rearing, the overall importance of the drainage for these species, and the existence of upstream barriers will inform resource management decisions within the watershed.

The specific project goals include:

- Describe current stream channel and fish habitat conditions
- Identify potentially suitable salmon and steelhead spawning habitat
- Determine spatial distribution and relative abundance of salmonids
- Identify and evaluate potential barriers to fish migration
- Establish baseline datasets for determining impacts to aquatic habitat that can be attributed to the implementation of land management activities
- Establish and monument 2 permanent monitoring stations (in addition to three previously established) for the evaluation of potential changes to the physical habitat (e.g. spawning gravels), the physical processes (e.g. channel aggradation/degradation), and relevant water quality parameters (e.g. stream temperature)

The field protocol described herein was developed to meet these goals. As requested by the project sponsors, the Clearwater Basin Collaborative (CBC), the protocol is designed to provide data on habitat type frequency (e.g., pools, riffles and runs), percent canopy cover, dominant vegetation type (trees/shrubs), substrate composition (including measures of cobble-embeddedness), locations of spawning habitat for salmonids, and fish distribution and relative abundance. TCBC requested that project data be collected using the Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventories Project Methods for Stream Habitat Surveys Protocol., or a similar protocol. In addition to the ODFW protocol, this protocol includes elements from several existing protocols, including the Columbia Habitat Monitoring Program (CHaMP), the EPA Environmental Monitoring and Assessment Program (EMAP), and the Washington Salmon Recovery Funding Board. CHaMP is a fish-centric habitat status and trend monitoring program designed for implementation across the range of salmon and steelhead in the Columba River Basin. The CHaMP protocol measures the quantity and quality of, and changes in, stream habitat for salmonid fishes. EMAP was initiated by EPA to estimate the status and trends of the nation's ecological resources and examine associations between ecological condition and natural and anthropogenic influences. The surface water component of EMAP is based on the premise that the condition of stream biota can be evaluated by examining biological and ecological indicators of stress.

To record data in the field, Stillwater Sciences used Sitka Technologies' iPad-based environmental monitoring data collection platform, known as GeoOptix. GeoOptix currently utilizes CHaMP, Washington Salmon Recovery Funding Board, and EMAP protocols. The combination of these protocols on the GeoOptix platform collect much of the same data as the ODFW protocols in a very similar fashion and the final data generated are comparable.

A draft of the field protocol present herein was initially reviewed by members of the CBC and Dr. Colden Baxter of Idaho State University. Additionally, while many of the methods provided here were originally derived from existing protocols such as CHaMP, site-specific conditions and logistical constraints related to simultaneous collection of many data types in the largely inaccessible Clear Creek drainage necessitated some minor modifications of existing methods. Moreover, following implementation of the project, several changes were made to certain components of the field protocol to improve clarity or reflect minor changes in methods that were imposed during field implementation. Finally, were applicable, specific analytical methods used to summarize and report project data were added to this protocol so that it can serve as a stand-alone reference document for future data collection efforts and analyses.

2 FIELD PROTOCOLS

Collection of fish and habitat data was carried out at two scales: reach-scale and habitat unit-scale. A reach is a length of stream defined by one or more functional characteristic. In general, reaches are segments of the stream with consistent valley width, channel gradient, and channel formation processes (geomorphology). Reaches are further defined by major changes in vegetation type, changes in land use, and location relative to major tributaries. The process by which reaches were identified for this project is described in a separate sampling framework document (Stillwater Sciences 2015, Appendix A). For the purposes of this survey, reach-scale data is considered to be all data collected less frequently than every habitat unit. These data include channel form and constraining features, riparian vegetation, fish distribution and abundance, and fish passage barrier identification and characterization (Table 1). Within each study reach, and ideally within each stream, field crews should collect reach-scale data while moving from downstream to upstream. Reach-scale protocols are described in Section 2.1.

Habitat units (channel geomorphic units) are relatively homogeneous lengths of the stream that are classified by channel bed form, flow characteristics, and water surface slope. With some exceptions, habitat units are defined to be at least as long as the active channel is wide. Individual units are formed by the interaction of discharge and sediment load with channel resistance (roughness characteristics such as bedrock, boulders, and large woody debris). For the purposes of this survey, habitat unit-scale data is considered to be all data collected at every habitat unit, which includes habitat type, habitat unit dimensions (width, length, water depth), substrate composition, incidence of bank undercut and erosion, large wood debris abundance, and suitable spawning gravel abundance (Table 1). As with reach-scale data, habitat unit-level data should be collected while moving from downstream to upstream within each study reach. Habitat unit-scale protocols are described in Section 2.2.

In addition to reach-scale and unit-scale data, two permanent monitoring stations were established for more intensive monitoring of stream channel physiography, stream discharge, stream bed surface substrate, cobble embeddedness, water temperature, and fish population abundance (Table 1). Monitoring Station establishment and data collection are detailed in Section 2.3.

Table 1. Data elements collected at each spatial scale.

Reach-scale	Habitat unit-scale	Long-Term monitoring stations
• Channel form and constraint • Cobble embeddedness • Riparian vegetation • Canopy cover • Fish distribution and abundance (snorkel surveys) • Presence of fish passage barriers	• Channel type classification • Habitat type classification • Channel dimensions • Substrate composition • Bank undercut and erosion • Large woody debris abundance • Spawning gravel	• Stream channel physiography • Discharge • Bed surface substrate • Cobble embeddedness • Air and water temperatures • Fish abundance (electrofishing)

2.1 Reach-scale Data Collection

2.1.1 Channel form and constraining features

Characterizing river reaches based on their channel form and constraining features helps to identify locations that may respond to disturbance, protection, or restoration in similar ways due to physical and habitat conditions. The protocol for describing channel form and constraining features presented below is based on the Washington Salmon Recovery Funding Board protocol (Crawford 2011) and collects much of the same information as the ODFW protocol while using somewhat different terminology. The channel form attributes described below were collected at least once in each identified reach. In reaches longer than 1,000 m, these attributes were measured approximately every 500 m. All channel form and constraint measurements were collected at channel cross-sections (transects) located within a representative riffle in each reach where the channel is relatively straight. Channel form, constraining features, and percent constraining were evaluated at the scale of a full channel meander/bend that encompasses the transect. This channel length can be approximated as 20 times the bankfull width (with the transect in the middle).

Step-by-step instructions

1. **Select representative location.** When practical, select transect locations for reach scale measurements within the middle 50% of a reach (or sub-reach if multiple transects are to be surveyed in a given reach) and record the habitat unit number in the appropriate data form. Transects should be selected in first riffle near the reach midpoint considered representative and of sufficient length. Selected riffles should be relatively long and straight and located in a crossover unit (between habitat units with scour on opposite sides of the channel) within a channel segment that is also relatively straight. Exact transect locations within each riffle should be selected based on professional judgment to facilitate measurements and avoid anomalous or unique channel characteristics. When possible, avoid locations where there is strong channel planform or valley curvature, unless this typifies the overall reach character.

In reaches greater than 1,000 m, multiple, evenly-spaced reach-scale characteristics were measured at transects as follows:

Reach length (m)	Number of reach-scale transects to survey
<1,000	1
1,000–1,499	2
1,500–1,999	3
>2,000	4

2. **Collect GPS coordinates**. GPS coordinates were collected in the center of the reach transect. To assist with re-locating transects, their locations were also marked with flagging and small aluminum tags.
3. **Classify channel form.** Classify the predominant channel form for the stream reach (over a channel length approximately 20 times the bankfull width) at the transect location as one of the following:
   a. Single channel: a single-thread channel that does not branch.
   b. Anastomosing channel: a channel with relatively long major and minor channels branching and rejoining in a complex network.
   c. Braided channel: A channel also comprised of multiple branching and rejoining channels, but with sub-channels that are generally smaller, shorter and more numerous, often with no obvious dominant channel.
4. **Classify channel constraint.** For the evaluated channel length, determine whether the channel is:
   a. constrained within a narrow valley;
   b. constrained by local features within a broad valley;
   c. unconstrained and free to move about within a broad valley and flood plain; or
   d. free to move about, but within a relatively narrow valley floor.
5. **Evaluate constraining features.**
   a. Examine the channel to ascertain the bank and valley features that constrain the stream. Enter the dominant type of constraining features as one of the following: bedrock, hillslopes, terraces/alluvial fans, and human use (e.g. road, dike, landfill, riprap, etc...).
   b. Estimate the percent of the channel margin in contact with constraining features for the evaluated channel length (approximately 20 times the bankfull width). For unconstrained channels percent containment is 0%.
6. **Estimate bankfull depth.** Bankfull depth is measured from the channel thalweg to the elevation where over-bank flow begins during a flood event (bankfull level), or at the ordinary high water (OHW) level in a constrained channel. In unconstrained channels, bankfull level is the point where over-bank flow begins during a flood event. This level can be identified by interpreting evidence of bankfull flow atop the stream's banks (Figure 1). The most consistent indicators of bankfull flow are areas of deposition, as the top of these deposits (i.e., gravel bars) typically define the active floodplain (USFS 2006). Other bankfull indicators include:
   - a change in vegetation (i.e., from none to some, or from herbaceous to woody);
   - a change in bank topography (a change in slope of the bank above the water's edge);

- a change in the particle size of bank material, such as the boundary between coarse cobble or gravel and fine-grained sand or silt;
- a line defining the lower limit of lichen colonization on boulders or bedrock;
- a stain line visible on bare substrate such as bedrock;
- a defined scour line (exposed roots, etc.); and
- a line of organic debris on the ground (but not debris hanging in vegetation) (USFS 2006).

Refer to Harrelson et al. (1994) for additional discussion of bankfull indicators.

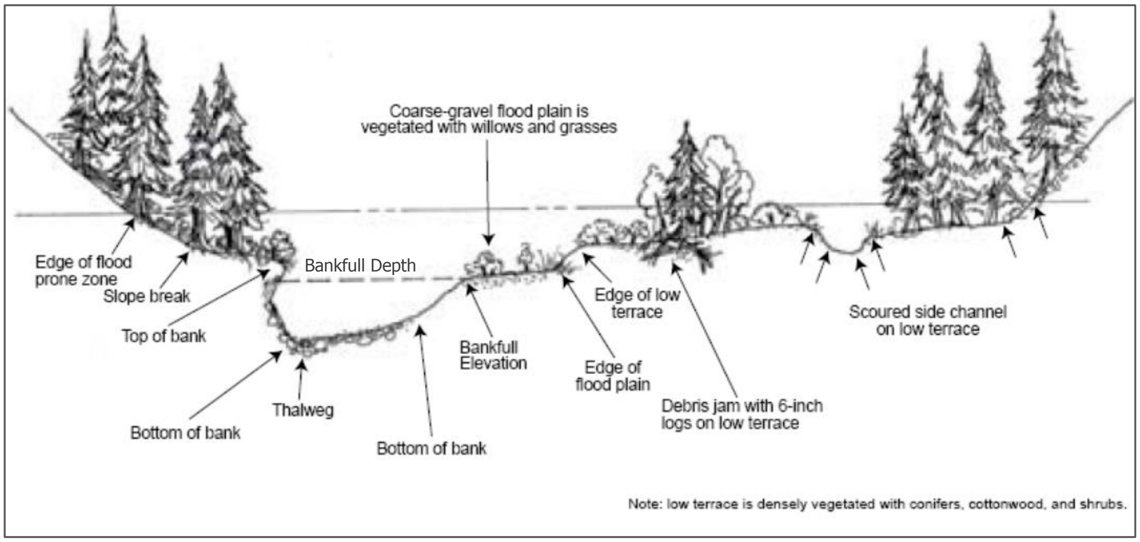

Figure 1. Illustration of bankfull width and other stream features (adapted from Groenier and Gubernick 2010).

Bankfull depth was measured with a hand level, clinometer or laser rangefinder and a survey rod. One crew member (the surveyor) records elevations (or rod heights) of the channel thalweg and bankfull level, while the other crew member (the rod holder) holds the rod. Steps for estimating bankfull depth include:

a. Identify locations of the thalweg and bankfull elevation at the transect using the indicators described above.
b. The surveyor should then stand straight-up, in a location higher than the bankfull elevation where he or she can see both the bankfull elevation and the adjacent thalweg of the transect.
c. The rod holder should then place the survey rod on the stream bottom at the thalweg and hold it vertically (#1 in Figure 2).
d. The surveyor views the survey rod through a clinometer or rangefinder and records the height of the rod that is level with their eye height.
e. Next, the rod holder moves and places the survey rod at the bankfull elevation of the transect (#2 in Figure 2).
f. Without moving, the surveyor look sat the rod through a clinometer or rangefinder and records the rod height at the bankfull elevation that is level with their eye height.

g. Finally, the bankfull depth is calculated by subtracting the rod height at bankfull elevation from the rod height at the thalweg elevation.

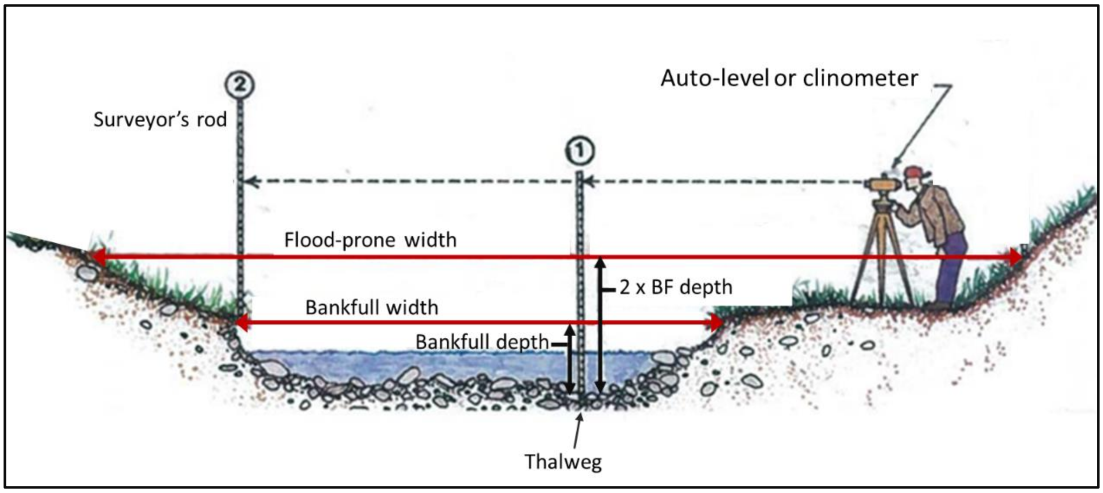

Figure 2. Measuring bankfull depth and bankfull and flood-prone widths (modified from Rosgen and Silvey 1998).

7. **Measure bankfull width.** Measure the bankfull width with a tape or laser range finder. Bankfull width is the distance between the left bank and right bank at the point where over-bank flow begins during a flood event (bankfull elevation), or at the OHW level in a constrained channel. See the description of bankfull and OHW indicators in Step 6 above.
8. **Measure flood-prone width (FPW)**. Flood-prone width is defined as the channel width at an elevation twice the bankfull depth elevation. Estimate the flood-prone width at each transect by using a clinometer to shoot from the edges of the flood-prone area to the survey rod placed in the thalweg at an elevation twice the bankfull depth.
9. **Take representative photographs.** Take photographs upstream and downstream from one of the transect end points and again from mid-channel to document conditions in the vicinity of the transect.
10. **Measure substrate embeddedness.** The abundance of fine particles in the streams could be affected by forest management practices, and therefore an evaluation of particle embeddedness will provide valuable data to track long-term trends.
    a. Embeddedness is measured for approximately 20 cobble particles (64–256 mm b-diameter) within riffles where reach-scale measurements are collected. Particles are selected at random by a walking up the habitat unit, pausing at approximately 20 equal intervals so as to make measurements at 20 locations. At each pause, a random number (10–90%, in 10% intervals) is selected which directs the measurer to choose a location that corresponds to that percentage of the total distance across the channel (as consistently estimated from one of the two banks). At that location, a "step-toe" procedure is used (as described by Harrelson et al. 1995), and the closest cobble particle to the toe is selected for the embeddedness measure (up to about 1 m). Particle embeddedness is estimated based on the depth of burial and stain lines on the cobble.

2.1.2 Riparian vegetation

Riparian vegetation was defined for these surveys as vegetation within 10 meters of either side of the active stream channel. Data on both dominant and subdominant plant communities, based on visual estimation, were recorded for each side of the stream channel at selected transects (note: in some instances grass can be the dominant plant taxa). Transects for recording riparian vegetation data were the same as the transects used for channel form and constraint data. Riparian transects began at bankfull width or where the initial band of riparian trees started, whichever cames first. Transects were selected to be perpendicular to the main axis of the stream and were 10 meters wide by 10 meters long (see Figure 3). One member of the survey crew should extend a tape measure out from the stream 10 meters (if feasible—do not risk injury or death to perform this task). If impassable terrain makes it impossible to walk 10 meters out from the stream, visually estimate the distance. The other crew member follows with the data sheets or iPad and records the measurements his/her survey partner calls out using the procedures described below.

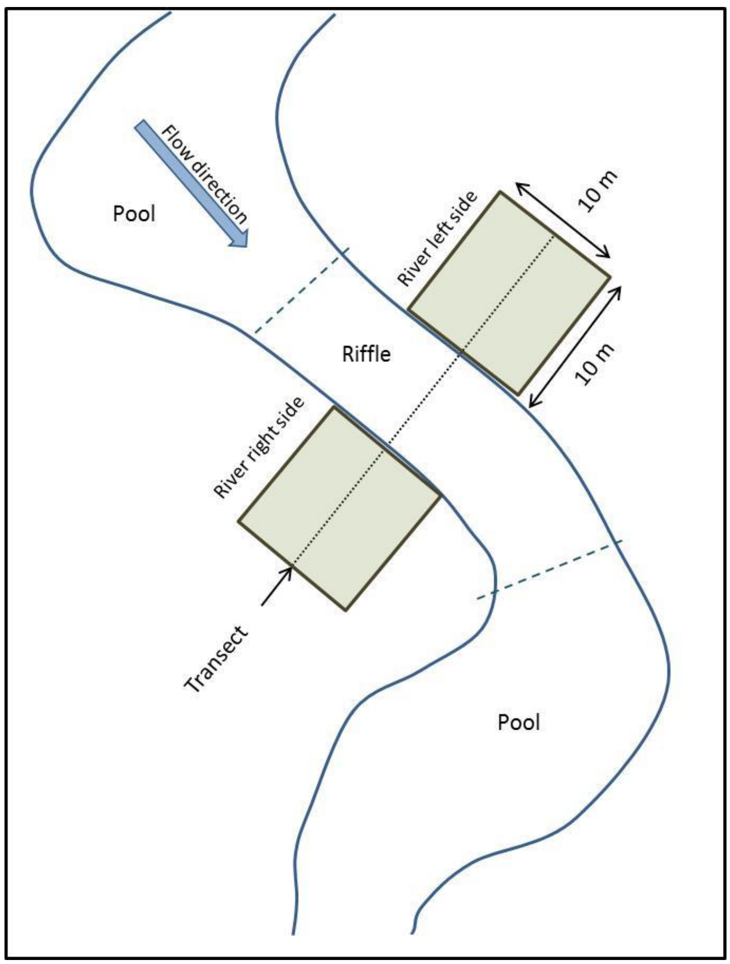

Figure 3. Example showing location of riparian vegetation transect.

Step-by-step instructions

The following vegetation data were recorded for both the left bank and right bank portions (5x10 m each) of each riparian transect:

1. **Unit number.** Record the habitat unit at which the transect is established.

2. **Side of channel.** Left or right side of the channel where data are collected when facing downstream.
3. **Vegetation type and size.** Record alpha numeric codes for both the dominant and subdominant vegetation types found on each side of the transect. The first part of the code (letter) identifies the vegetation type and the second part (number) refers to the size of the vegetation, estimated as diameter at breast height (dbh) in centimeters for the most prevalent size of trees. Use the bold letters and numbers provided in the Vegetation Type and Size Class code lists (below). For example: "C30" (dominant) and "D3" (subdominant), would indicate dominant conifers in the 30–50 cm size class, and subdominant deciduous trees in the 3–15 cm size class. Do not record a numeric size class code for brush, shrubs, or grasses. For example, dominant grasses would simply be recorded as "G".

   Vegetation Type Codes:

   - **N: N**o vegetation (bare soil, rock)
   - **B**: **B**rush (sagebrush, greasewood, rabbit brush, etc.)
   - **G**: Annual **G**rasses, herbs, and forbs.
   - **P**: **P**erennial grasses, sedges, rushes, and ferns
   - **S**: **S**hrubs (willow, salmonberry, some alder)
   - **D**: **D**eciduous dominated (canopy more than 70% alder, cottonwood, big leaf maple, or other deciduous spp.)
   - **M**: **M**ixed conifer/deciduous (~ 50:50 distribution)
   - **C**: **C**oniferous dominated (canopy more than 70% conifer)

   Size Class Codes:

   - **3** cm (<1 in): Seedlings and new plantings.
   - **3**–15 cm (1–5 in): Young established trees or saplings.
   - **15–**30 cm (6–11 in): Typical sizes for second growth stands. West side communities may have fully closed canopy at this stage.
   - **30-**50 cm (12–20 in): Large trees in established stands.
   - **50**–90 cm (21–35 in): Mature timber. Developing understory of trees and shrubs.
   - **90+** cm (36+ in): Old growth. Very large trees, nearly always conifers. Plant community likely to include a combination of big trees, snags, down woody debris, and a multi-layered canopy.

4. **Surface type.** Record the dominant geomorphic surfaces observed within each 10x10 riparian transect. Surface codes include:
   - **FP**: Flood Plain
   - **LT**: Low Terrace (height is < Flood Prone Height)
   - **HT**: High Terrace (height is > Flood Prone Height).
   - **HS**: Hill Slope
   - **SC**: Secondary Channel
   - **TC**: Tributary Channel
   - **IP**: Isolated Pool or unconnected valley wall channel.
   - **WL**: Wetland bog or marsh with no obvious channel.

- **RB**: Road Bed (indicate surface type, i.e. pavement, gravel)
- **RG**: Railroad Grade
- **RR**: Rip Rap

5. **Slope.** Measure the percent slope of the dominant ground surface in the transect using a clinometer.
6. **Canopy Closure.** The percent canopy closure is measured with the densiometer while standing in the middle of the 10x10m riparian transects on either side of the creek. Include the influence of both conifer and hardwood species. Densiometer procedures are described in Section 2.1.2.2 below.
7. **Shrub Cover.** The percentage of ground cover provided by shrubs. Include blackberry, thimbleberry, dogwood, willow, alder, etc. Small trees (seedlings and saplings less than 8 feet high) should be included in shrub cover. Estimate within 5% increments.
8. **Tree Group.** Conifer or hardwood.
9. **Riparian Note.** Optional comments that describe tree species or the plant community, large woody debris, invasive plants, or characteristics of snags or old stumps. Note presence or absence of large down wood in riparian zone. Record the riparian photo number and time in this column as well.
10. **GPS.** Record the UTM coordinates of the riparian transect in the center of the channel.

2.1.3 Stream canopy cover

Stream canopy cover were measured at each transect where riparian vegetation and channel form and constraint data are collected. The ODFW protocol described above for riparian transects does not include a measurement of canopy cover (the percentage of the sky covered by overhead vegetation) above the stream. The CBC has requested that percent canopy cover be reported, thus we used the methodology described below from the Washington Salmon Funding Recovery Board (Crawford, 2011b)

A convex spherical densiometer (Model A) was used to determine stream canopy cover at each transect. A total of six measurements were be obtained along the transect: four at mid-channel and once at the wetted edge of each bank as described below.

Step-by-step instructions

1. Stand in the stream at mid-channel of the transect and face upstream.
2. Hold the densiometer 0.3 m (1 ft) above the stream, keeping it level using the built-in bubble level. Move the densiometer in front of you so that your face is just below the apex of the taped “V”.
3. Count the number of grid intersection points within the “V” that are covered by either a tree, a leaf, a high branch, or other shade providing feature (Reed canary grass, bridge or other fixed structure, stream bank, etc.). Record the value (0–17) in the CENUP field of the canopy cover measurement section of the form.
4. Repeat steps 2 and 3 three more times while facing the left bank, downstream, and right bank. Record the left bank value in CENL field of the data form, the downstream value in the CENDWN field, and the right bank value in the CENR field.

5. Repeat steps 2 and 3 again, while standing at the wetted edges of each bank and facing the bank. Record values for the left bank in the LFT and for the right bank in RGT fields of the data form.
6. If for some reason a measurement cannot be taken, indicate in the "Flag" column. This situation would occur if there is no access to one side of the channel, or if the channel is too wide or deep to cross, so middle measurements cannot be taken. Do not estimate measurements if they cannot be taken.

Analytical methods

For comparison with Oregon Benchmarks, canopy closure was averaged for the center of the stream channel and channel margins separately (OWEB 1999). For example, to average the channel center readings, the total number of grid intersections with shade from the four readings were divided by 68 (17 x 4). For comparison with Idaho benchmark values, the channel center and margin readings were averaged together (Grafe 2002).

2.1.4 Fish distribution and relative abundance (snorkel surveys)

Single-pass snorkel surveys were conducted in every 5th pool to determine distribution and relative abundance of the target species. For each study reach, the first pool encountered was snorkeled then every fifth pool thereafter was snorkeled. For each field crew, every fifth pool of the snorkeled pools (regardless of reach) was sampled with 3-passes (effectively every 25th pool) using the same process on the 2nd and 3rd passes described below for the 1st pass. The three-pass approach allows the fish population to be estimated using a bounded-count estimator and is intended provide insight into observation probability of single-pass snorkeling.

When a pool unit to be snorkeled is encountered, field crews implemented the following procedure (modified from the CHaMP protocol).

Step-by-step instructions

1. Measure and record the water temperature in degrees Celsius.
2. Begin snorkeling at the downstream boundary of a pool unit and proceed upstream, counting fish until reaching the upstream boundary. In larger and wider habitat units, field crew members may need to snorkel side-by-side and sum their individual counts.
3. Record fish counts by species and size class on dive slates and transfer data to field forms after snorkeling. Assign counted fish to 50 mm length bins, using a scale on the dive slate to facilitate estimation of fish length. Record young-of-the-year (YOY) fish too small to accurately identify to species (e.g., *O. mykiss* vs. cutthroat trout) and other fish that cannot be identified as unidentified trout.
4. For multi-pass surveys, record fish counted by pass number.
5. After snorkeling, rank and record the underwater visibility of each study reach on a scale of 0 to 3, with0 being not snorkelable due to extremely high amounts of hiding cover and/or no visibility, and 3 being little hiding cover and good water clarity. Only reaches with a visibility rank of two or three were used in data analysis.
6. When encountering a potential barrier to anadromous fish distribution, the first pool upstream of the potential barrier should be snorkeled. If sampling the first pool upstream of the barrier does not indicate presence of anadromous fish, the second and third pools should be sampled to lend evidence to the absence of anadromous fish above the barrier. If anadromous fish are observed upstream of a potential barrier, sampling would continue in every fifth pool as described above, starting with the last pool snorkeled. If no anadromous

fish are observed in the first three pools above the barrier, but resident fish are observed in one or more of the pools, fish distribution and abundance sampling would continue for resident fish in every fifth pool as described above.

7. When encountering a potential barrier to resident salmonid distribution (upstream of a documented anadromous barrier, where resident salmonids have been observed in one or more reaches immediately downstream of a potential barrier) the first pool upstream of the potential barrier should be snorkeled. If sampling the first pool upstream of the barrier does not indicate presence of resident fish, the second and third pools should be sampled to lend evidence to their absence above the barrier. If no fish are observed in first three pools sampled upstream of the potential barrier, fish distribution and abundance sampling should be discontinued. If resident fish are observed upstream of the potential barrier, sampling would continue in every fifth pool as described above. In the absence of obstacles identified as potential barriers to resident fish, fish distribution and abundance sampling should continue until fish are not observed in three consecutive pool habitat units sampled.

Daytime snorkel counts are generally expected to underestimate actual fish abundance and also have the potential to miss rare or more nocturnal species such as bull trout. However, because of the logistical challenges of working during both day and night in the remote Clear Creek study area, it is infeasible to conduct regular snorkel surveys at night. Nonetheless, in order to inform differences between day and night, night snorkeling may be conducted opportunistically at a subset of pools.

Analytical methods

Fish distribution was summarized using all available information, including snorkel data, definitive observations (e.g., adult Chinook salmon) during collection of habitat unit-scale data, and electrofishing of monitoring stations.

Relative abundance results were summarized for each species as the number of fish counted per 100 m of pool length using single-pass snorkel data only. Pool lengths used for relative abundance analyses were derived from pool measurements made during habitat typing (Section 2.2.3). For these analyses, trout that could not be identified (unknown trout) were assumed to be O. mykiss for reaches in which *O. mykiss* were definitively present. For reaches where *O. mykiss* were not definitively observed, unknown trout were assumed to be cutthroat trout.

Multi-pass snorkeling data—along with limited night snorkeling and limited comparisons of fish counts from pools snorkeled then electrofished—were used to help evaluate observation probability. Abundance estimates were calculated from three-pass counts for cutthroat trout and *O. mykiss* by size class for each pool in which they were present and compared with single-pass counts.

2.1.5 Fish passage barrier identification

All potential migration barriers to anadromous fish were identified and photographed, and a GPS location was be recorded. Both natural features such as waterfalls and manmade structures such as perched culverts should be documented.

Natural barriers are permanent structures blocking fish migration. These features can be divided into: (1) physical barriers and (2) hydraulic barriers

Physical barriers are features such as waterfalls or other vertical drops with one or more of the following characteristics:

- More than approximately six to eight feet high for salmon and steelhead and four feet high for resident trout.
- Require an excessive horizontal jump distance (horizontal distance from downstream pool to crest) in combination with vertical jump height.
- Lack downstream pools with adequate depth for fish to successfully jump (typically 1.25 times deeper than the jump height)

Hydraulic barriers are features such long, high-gradient cascades or steep bedrock chutes with:

- Water velocities in excess of a species' maximum swimming speed with few or no locations for resting
- Inadequate water depths for a fish to swim through (e.g., sheeting flow over bedrock or sub-surface flow or reaches with only sub-surface flow)

For the purposes of this evaluation, we measured key dimensions of, photographed, and GPSed all features that had the potential to be total permanent barriers to salmon or steelhead based on the factors described above. Significant log jams, drops over logs, beaver dams, or other organic structures that constitute a passage barrier are considered temporal barriers, and were documented with a photograph (with stadia rod for scale) and GPS location.

For each potential permanent natural barrier to anadromous fish encountered, the following information was measured (when safe/feasible) or estimated (when not safe):

1. **Type of barrier** (physical or hydraulic)
2. **Jump height.** Vertical distance measured from the water surface of the jump pool to the water surface upstream (crest).
3. **Jump distance.** Horizontal distance from jump pool to water surface upstream.
4. **Jump pool depth.** Maximum depth of pool at the base of the feature.
5. **Lengths of bedrock chutes or cascades** that are potential barriers and relevant notes on:
    a. Presence and location of small pools or other low velocity areas (boulders or breaks in flow) for resting within the feature.
    b. Water depths and whether water flows over bedrock in an even shallow pattern (sheeting)
6. **Percent slope of bedrock chutes or cascades** (measured with a clinometer).
7. **Notes and photographs** of any other items pertinent to fish passage conditions, such as presence of significant hydraulic control features downstream that may cause backwatering at higher stream flows (thus lowering jump height).
8. **Depth of the hydraulic control**. Measure depth of hydraulic control point downstream of the potential barrier if present (e.g., pool tail crest).

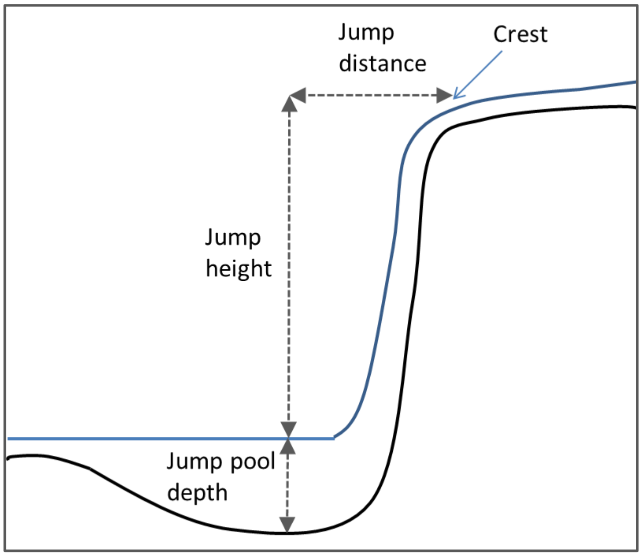

Figure 4. Diagram showing key features to be measured when assessing a physical migration barrier.

Analytical methods

Following field assessments, each potential barrier identified was assigned to one of the following general categories based measured data, field notes, photographs, and professional judgement:

- *Not a barrier*: Feature was determined to be at most an obstacle to fish migration, but not expected to be a barrier to passage at the majority of stream flows. These features were not reported here.
- *Seasonal barrier - low*: Feature likely represents a migration barrier at a relatively narrow range of stream flows and thus is passable at a relatively wide range of stream flows.
- *Seasonal barrier – moderate*: Intermediate between *Seasonal barrier – low* and *Seasonal barrier – high.*
- *Seasonal barrier – high*: Feature likely represents a migration barrier at a relatively wide range of stream flows and thus is passable at a relatively narrow range of stream flows.
- *Likely total barrier:* Feature is expected to be a total barrier to fish migration across all stream flows.

All culverts encountered within study reaches should be photographed and GPS coordinates taken. In addition, the following information should be recorded:

1. Material
    a. Plastic
    b. Steel
    c. Concrete
2. Shape
    a. Round
    b. Arch
    c. Box
3. Length (from inlet to outlet)

4. Diameter (measured at outlet)
5. Slope, measured with a clinometer
6. Jump height (height from the surface of the stream at the base of the culvert to the outlet / lip of culvert)
7. Jump pool depth
8. Presence of baffles or other internal features
9. Notes on factors pertinent to fish passage.

2.2 Habitat Unit-scale Data Collection

All habitat unit-scale data collection procedures are modified from the CHaMP protocol. The CHaMP protocol classifies habitat units in a very similar fashion to the ODFW protocol.

2.2.1 Main and side channels

Channel segment numbers were used to differentiate the main channel from side channels. A channel segment number was assigned to all habitat units within the main channel and qualifying side channels as described below.

Step-by-step instructions

1. **Identify the main channel.**
    a. Main (primary) channel: Contains the greatest amount of stream flow at a site.
2. **Identify side channels.**
    a. Side channel: To be considered a side channel, the channel must be separated from another channel by an island that is ≥ the bankfull elevation for a length ≥ the average bankfull width.
    b. If a channel is separated from another channel by an island that is shorter than the average bankfull width, then consider the channel part of the adjacent channel.
    c. If a channel is separated from another channel by a bar (< bankfull elevation) or boulder, then consider the side channel part of the adjacent channel.
3. **Identify side channel type.**
    a. Determine if side channel is qualifying or non-qualifying.
        i) Qualifying side channel: Channel is located within the active bankfull channel and separated from another channel by an island ≥ the average bankfull width.
            (1) Qualifying side channels are further divided into large and small side channels
        ii) Refer to the decision tree in Figure 5 regarding segment number and habitat unit designations for qualifying side channels.
    b. Non-qualifying side channel: Channel is located outside the active bankfull channel or possesses one or more of the following characteristics:
        iii) The elevation of the side-channel's streambed is above bankfull at any point.
        iv) Side-channel lacks a continuously defined streambed or developed stream banks.
        v) Side-channel contains terrestrial vegetation.
    c. Determine whether qualifying side channel is large or small.
        vi) Visually estimate stream flow at both the upstream and downstream ends of the side channel as a percentage of the total flow at the site.

   d. Large side channel: Has between 16% and 49% flow at either end.
   e. Small side channel: Has < 16% flow at both ends.

4. **Assign segment numbers to channels.**
   a. The main channel is assigned “Segment 1” throughout the reach (Figure 5).
   b. The first large or small side channel encountered (moving upstream) is designated as “Segment 2”. Designate additional qualifying side channels sequentially (2, 3, 4, etc.) until all large and small side channels have been uniquely numbered (Figure 5).
   c. Do not assign segment numbers to non-qualifying side channels.
   d. Note: If a large side channel splits and each channel contains > 16% of the total stream flow, assign the original segment number to the largest channel and assign a new segment number to the second channel. If a large side channel splits, and flow in either channel is < 16% of the total flow, assign the original channel segment number to the largest channel, and assign a new segment number to the smaller channel (now considered a small side channel).

5. **Record measurements.** What to measure in each channel type:
   a. Main channel:
      i) Classify habitat units as described in Section 2.2.1.2 collect all habitat unit attributes described in Section 2.2.2
   b. Large side channels:
      i) Classify habitat units, collect all habitat unit attributes
   c. Small side channels:
      i) Classify the entire side channel (both wet and dry portions) as a Small Side Habitat unit (Figure 15C).
      ii) Quantify Large Woody Debris (Section 2.2.2.4). Do not collect any additional habitat unit attributes, aside from the following (iii through vi).
      iii) Categorize the side channel as continuously wet, partially wet, or dry.
      iv) Estimate the total length of the side channel centerline.
      v) Estimate the average bankfull width of the side channel.
      vi) Estimate the percent of the bankfull channel area that is wet at the time of sampling.
   d. Non-qualifying side channels:
      i) Take a GPS point where the side channel enters/exits the adjacent channel
      ii) Do not classify habitat units, collect any habitat unit attributes, or categorize side channel.
      iii) Do not estimate side channel length, width, or percent wetted.

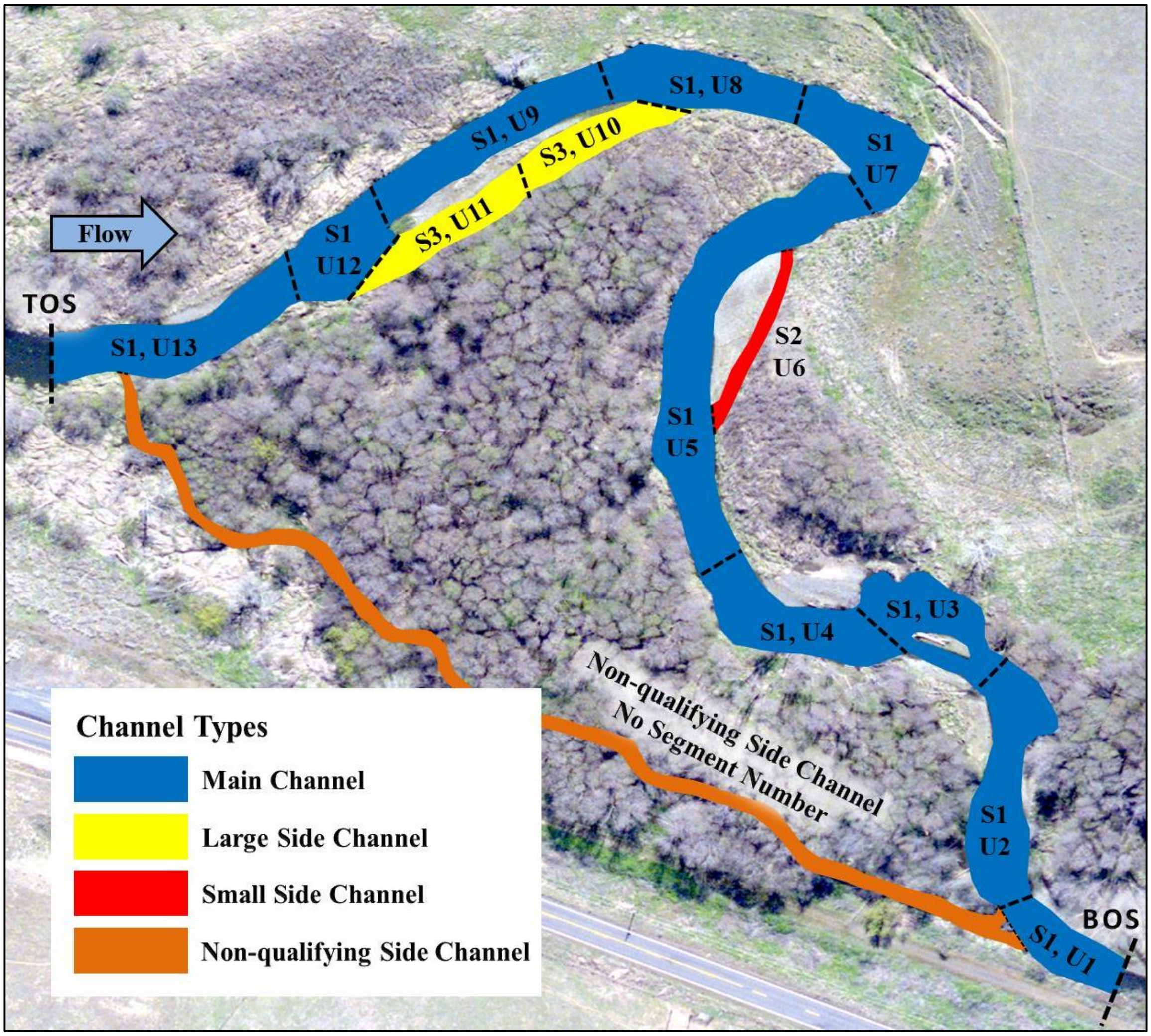

Figure 5. How to number channel segments within a site. The main channel is assigned Segment 1 throughout the site. Both large and small side channels are assigned sequential segment numbers working upstream. In the figure, channel segment numbers are preceded with an "S" (S1-S3) and habitat unit numbers with a "U" (U1-13).

2.2.2 Habitat unit types

Channel/habitat units are relatively homogeneous lengths of stream channel with consistent water surface gradient, bedform profile (channel topography), substrate composition, and flow characteristics. The identification of habitat units provides the context for the survey of fish habitat attributes and channel topography. Channel units are classified using a two-tiered system (Figure 6): Tier I and Tier II. Tier I units are Fast Water Turbulent, Fast Water Non-Turbulent, and Slow Water/Pool. Tier II classifications break Tier I units down to a finer scale. Generally, habitat units are at least as long as the wetted channel width. Figure 7 provides context in regards to the spacing and resolution of habitat units in a typical survey.

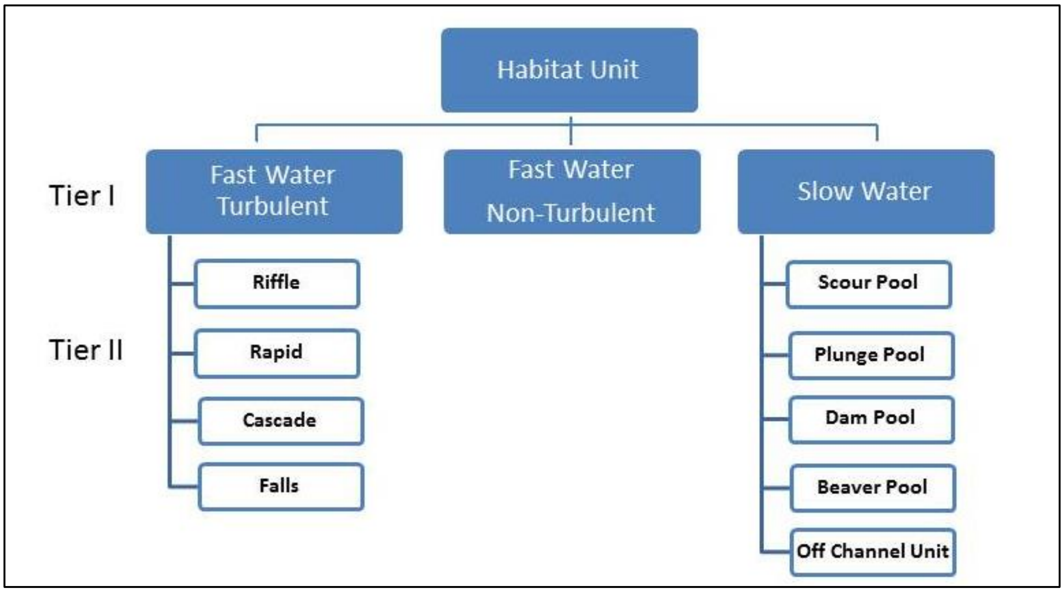

Figure 6. Hierarchical habitat unit classification system. Modified from Hawkins et al. (1993) and reported in Bisson et al. (2006).

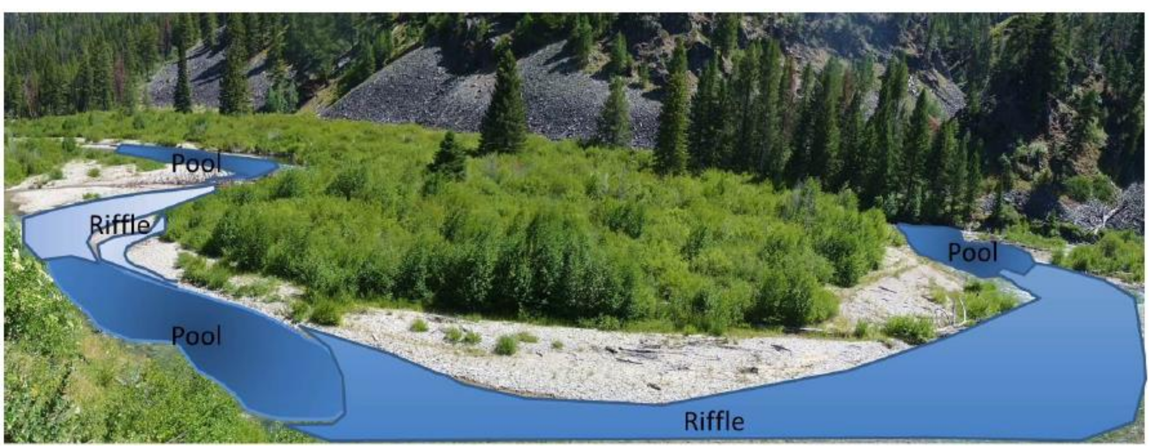

Figure 7. An example of habitat unit delineations (from CHaMP 2013).

Step-by-step Instructions

1. Determine habitat unit boundaries based on distinct changes in the following attributes (detailed in Table 2):
   - water surface gradient,
   - bedform profile (channel topography),
   - substrate composition, and
   - flow characteristics.

Table 2. Criteria used to delineate and classify Tier I habitat units (from CHaMP 2013).

Tier I classification	Gradient	Bedform profile	Substrate composition	Flow character
Fast water turbulent	>1%	Topographic high points in the bed profile	Generally have coarse substrate (cobbles and boulders)	Fast turbulent flow identified by white-caps and noise
Fast water non-turbulent	<1%	Uniform depth, low complexity	Generally small cobble gravels, and fine substrate	Smooth, even flow (laminar), no surface turbulence
Slow water/pool	0%	Pools are laterally and longitudinally concave (Figure 7); off channel units don't have flow through them.	Variable; generally sorted finer substrate or bedrock	Generally laminar flow

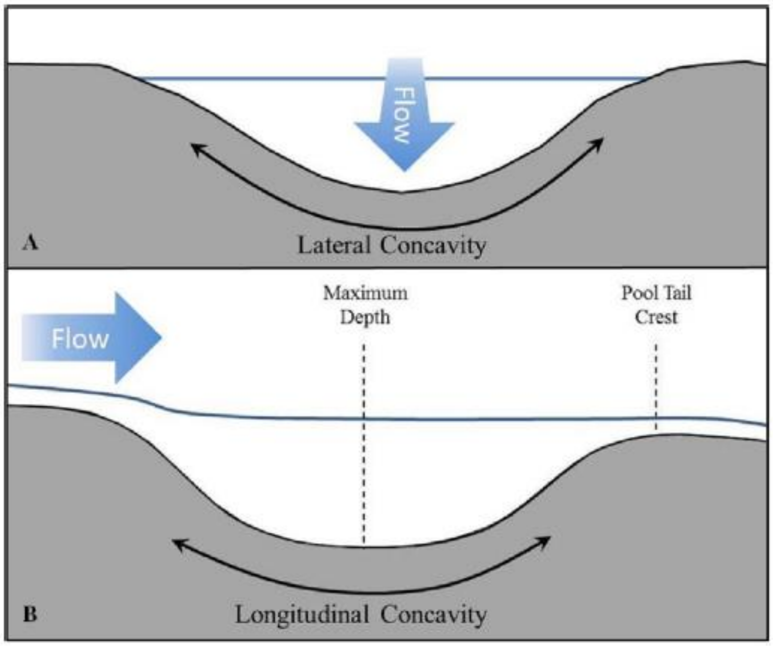

Figure 8. Diagrams showing (A) Cross-sectional (lateral) and (B) longitudinal concavity of pools (From CHaMP 2013)

2. **Classify habitat units.** Habitat units are classified according to a two-tiered hierarchical classification schema. Use the classification keys to determine the Tier I (Table 2, Figure 8) and Tier II (Figures 9 and 10) habitat unit classification for each unit identified at a site. Classification trees are read from top to bottom.
   a. Tier I
      ii. **Fast Water Turbulent** habitat units are topographical high points in the bed profile that feature moderate to steep gradients, coarse substrate, and tend to have turbulent flow. The bedform of these habitat units may lack longitudinal or lateral concavity.
      iii. **Fast Water Non-Turbulent** habitat units are topographical high points in the bed profile that feature low gradients, variable substrate composition, and smooth laminar flow. Fast water non-turbulent units often have low slope similar to pools but are distinguished from pools by their general lack of lateral and longitudinal concavity. These habitat units are generally deeper than riffles.
      iv. **Slow Water/Pool** habitat units are used to classify a variety of very low gradient pool and off habitat unit types. These units are generally topographical low points in the channel profile, feature smooth laminar flow, and have lateral and longitudinal concavity (Figure 7).
      v. **Culvert** If a culvert is encountered, treat it as a unit (assign it a unit number) and asses its barrier potential using the methodology in Section 2.1.4.
3. **Take photographs of features of interest** within each reach (barriers, LWD jams, spawning patches etc.) and of general stream features at least every five habitat units.

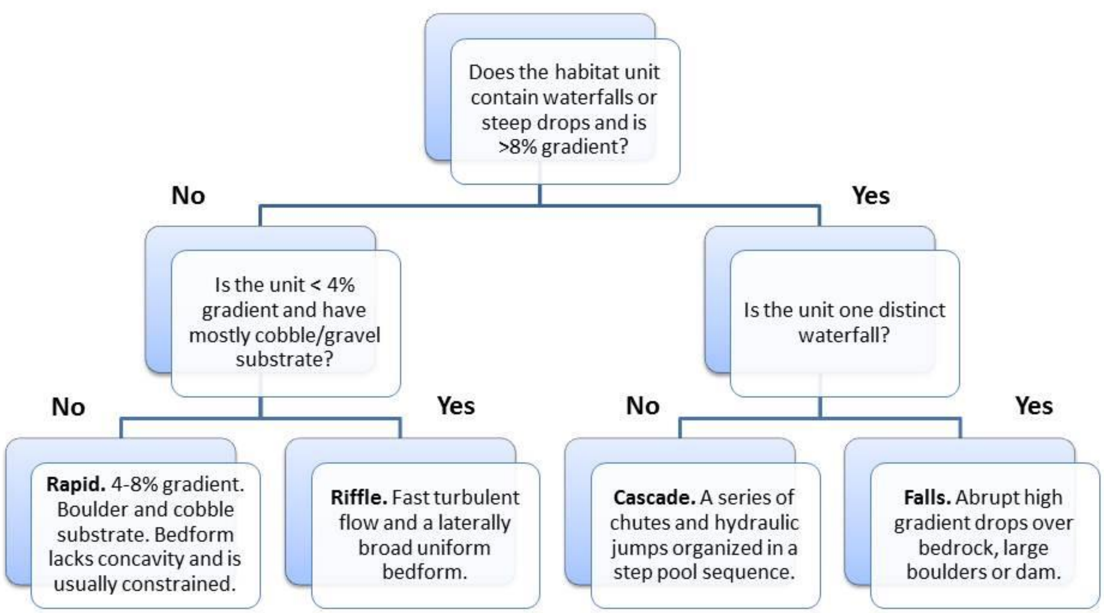

Figure 9. Dichotomous key outlining criteria used to classify Tier II fast water habitat units (from CHaMP 2013)

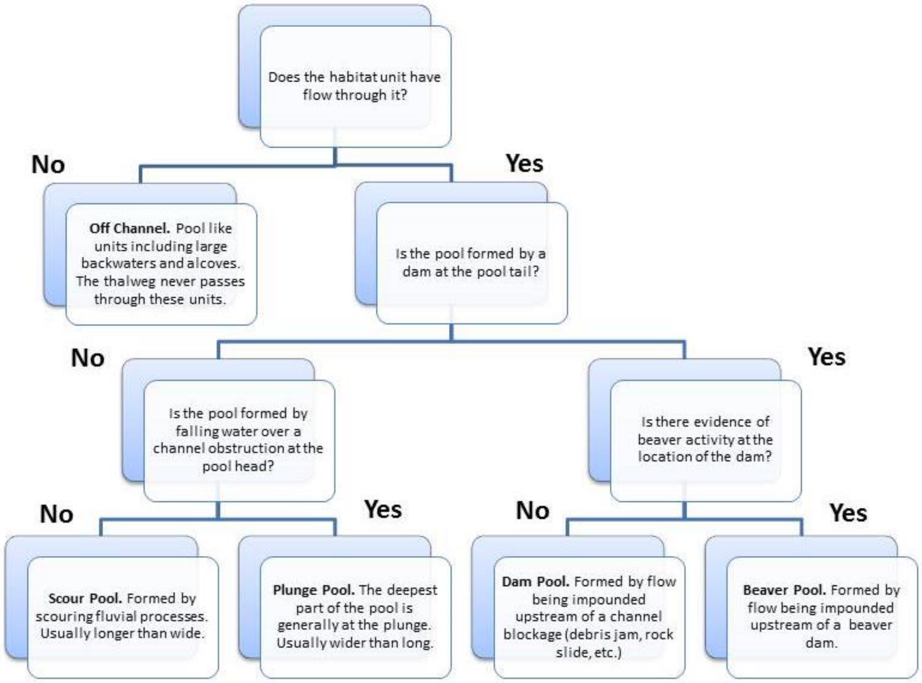

Figure 10. Dichotomous key outlining criteria used to classify Tier II slow water habitat units.

2.2.3 Habitat unit characteristics

Data on the following characteristics were collected in each habitat unit:

- channel dimensions,
- substrate composition,
- bank undercut and erosion,
- large woody debris abundance, and
- spawning gravel quality and abundance.

Field protocols for each are detailed in the sections below.

2.2.3.1 Channel dimensions

All channel width and length measurements were made with a tape, surveyor's rod, or laser range finder. Depth measurements were collected with a surveyor's rod.

Step-by-step instructions

1. **Width measurements:** Measure and record 2 to 5 wetted widths (depending on unit length) that are representative for each habitat unit in both primary and qualifying side channel segments.
2. **Length measurements**: Measure habitat unit length along the thalweg. Pools generally have zero slope, and length measurements should be made from the slope break at the head of the pool to the slope break at the tail of the pool.

3. **Depth measurements**: Take depth measurements in the thalweg at the same location where width measurements are taken. Additional depth measurements are taken in pool habitat for maximum depth, and estimate of mean depth, and pool tail crest depth. Measure and record the pools maximum depth and pool tail crest depth. The pool tail crest depth (hydraulic control) is measured at the thalweg of the pool tail, and is illustrated in Figure 7.

2.2.3.2 Substrate composition

Estimate the percentage of the wetted area of each habitat unit consisting of each substrate type (Table 3). Round each class to nearest 5% for a total of 100%. Use 1% to denote minimal presence.

Table 3. Substrate classification units.

Substrate type	Size class (mm)	Description
Bedrock	>4,000	Surface rock bigger than a car
Boulders	>250–4,000	Basketball to car size
Cobbles	>64–250	Tennis ball to basketball size
Coarse gravel	>16–64	Marble to tennis ball size
Fine gravel	>2–16	Small pebble to marble size
Sand	>0.06–2	Smaller than ladybug size, but visible as particles and gritty between fingers
Fines	<0.06	Silt, clay, muck, and not gritty between fingers

2.2.3.3 Bank undercut and erosion

Step-by-step instructions

1. **Estimate bank undercut.** Record the percent (by length) of the banks in each unit that are undercut. The undercut must have an average of 15 horizontal centimeters of immediate overhanging ceiling. Record for both left and right banks
2. **Estimate bank erosion**. Estimate the percent of the lineal distance in each unit that is actively eroding. Active erosion is defined as actively, recently eroding, or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability. Record for both left and right banks.

2.2.3.4 Large Woody Debris (LWD)

The LWD protocol described below is based primarily on CHaMP (2013), and specifies collection of much of the same data and in a similar manner as the ODFW protocol. The number and dimensions of qualifying LWD pieces in each habitat unit were quantified using the steps described below. In addition, qualifying wood jams were documented as described below.

Step-by-step instructions

1. **Determine if piece qualifies as LWD.** When a piece of wood is located, determine if it qualifies as LWD based on these qualifications:
    - Located within the bankfull channel and prism (including those pieces within large and small side channels). The bankfull prism refers to the area directly above the bankfull channel elevation (Figure 11).

- Is dead, with the exception of newly fallen trees that are uprooted from the bank but still have green foliage.
- Has a B-axis diameter ≥ 15 cm (6 in), measured at the midpoint of the piece. For LWD with attached roots, the diameter is measured at the midpoint between where the main stem joins the root mass (e.g., root collar) and the top of the piece (Figure 11).
- Is ≥ 3 m (10 ft) in length. The length of a piece of wood with attached roots is measured from the end of the main root mass to the top of the trunk.
- For LWD embedded in the stream bank, the exposed portion must meet the minimum length and diameter requirements to qualify and only the exposed portion should be measured.
- If a LWD piece is broken or cracked, consider it one piece if the two pieces are attached at any point along the break.

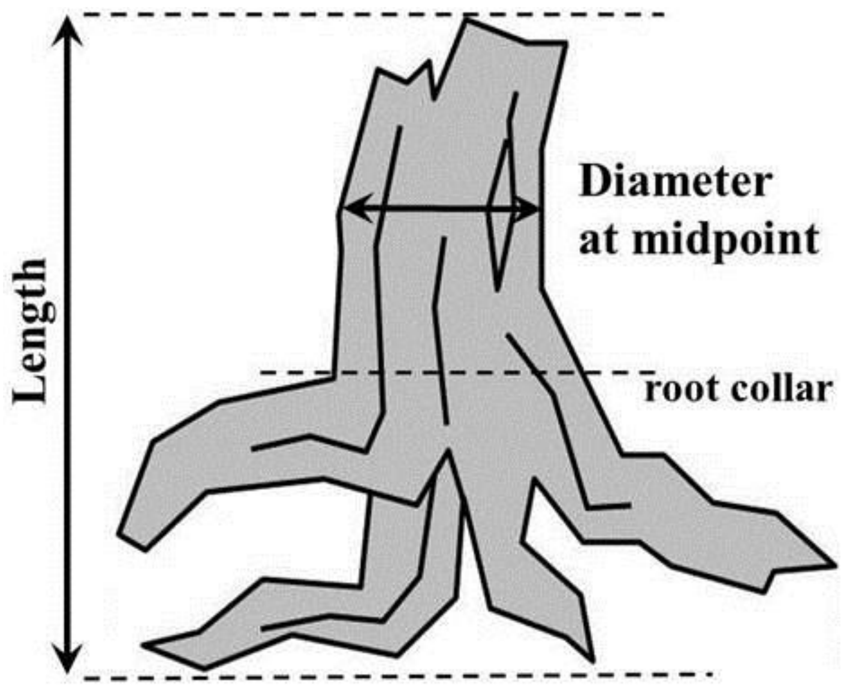

Figure 11. Depiction of diameter and length measurement locations for LWD with attached roots.

2. **Assign qualifying LWD pieces to a habitat unit** based on the following guidelines:
   - If a piece of LWD is present in two or more habitat units, assign it to the unit that contains the highest proportion of the piece's volume.
   - If a piece of LWD is outside wetted portion of the channel but within the bankfull channel, assign this 'dry' piece to the nearest habitat unit.
   - If the piece of LWD is part of a debris jam, indicate that on the data sheet.

3. **Classify as "wet" or "dry".** Classify qualifying LWD located within the bankfull channel or prism as "wet" or "dry" based on the following criteria (Figure 12):

- Classify piece as "wet" if any portion of the main stem or root that touches the water is ≥ 10 cm in diameter.
- Classify piece as "dry" if a portion of the main stem or root ≥ 10 cm in diameter is within the bankfull channel but outside of the wetted channel (i.e. would get wet at bankfull flows).
- Classify pieces outside the bankfull channel but within the bankfull prism as "dry" if they meet both of the criteria below.
  - Piece is in the bankfull prism and is suspended vertically above the bankfull channel by other pieces of LWD.
  - Piece would fall into the bankfull channel if the supporting LWD was removed
  - Note: These pieces frequently occur in large wood aggregates or "jams".

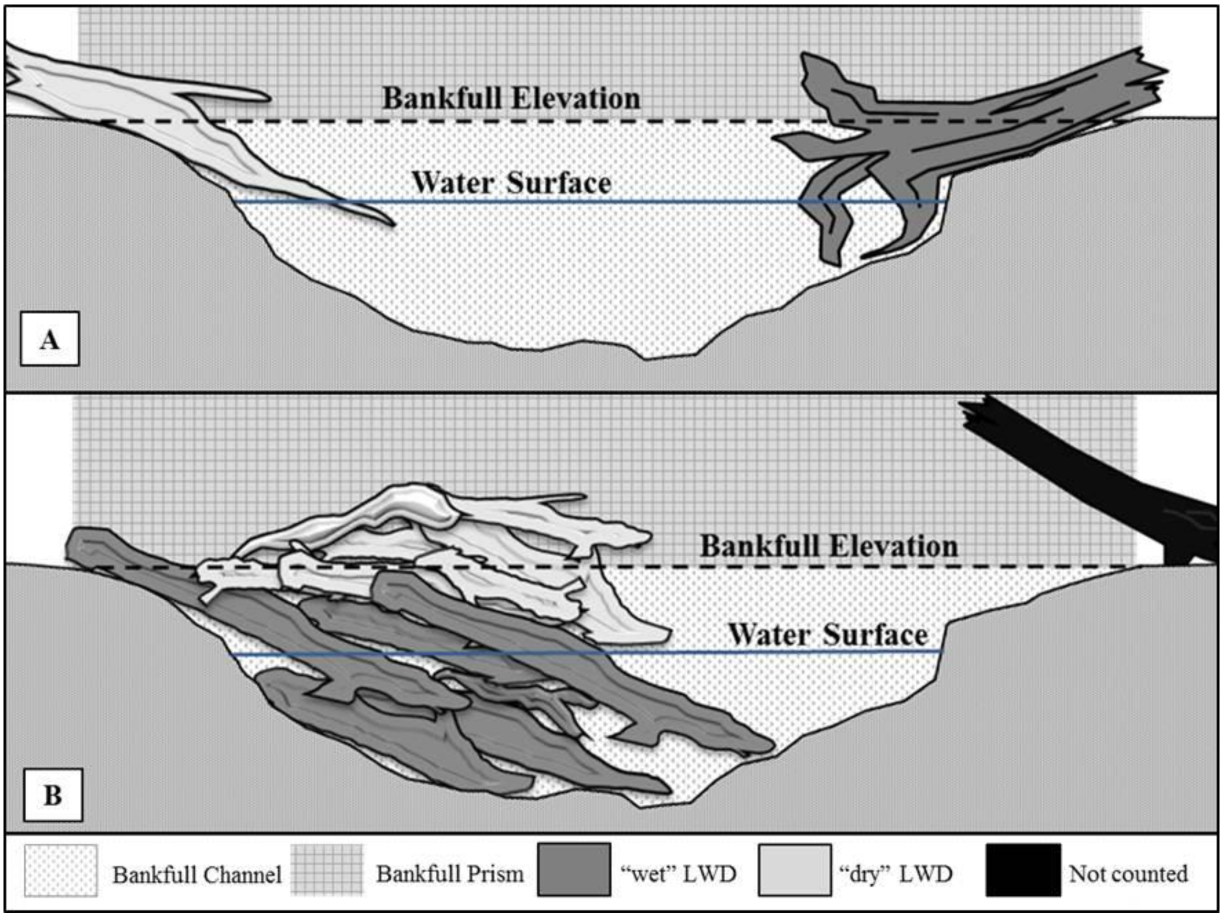

Figure 12. Cross-section view depicting LWD wet/dry scenarios for qualifying pieces. Grey pieces are classified "wet" and light grey pieces "dry". Panel A) LWD piece on left is "dry" because the portion of the main stem touching the water is < 10 cm. LWD piece on right is "wet" because a root ≥ 10 cm diameter touches the water. Panel B) Note that "dry" pieces above the bankfull elevation but within the bankfull prism are supported by other LWD pieces and are counted (see Step 3).

4. **Tally qualifying LWD pieces located within each habitat unit by length and diameter classes.** Measure (where feasible) or estimate length and diameter of each piece of LWD (refer to Figure 11 for guidelines on where dimensions should be measured) and record data by tallying the length and diameter classes presented in the following matrix.

Table 4. Length and diameter bins for assessing LWD.

Diameter class	Length class				
	3–6 m (10–20 ft)	**6–9 m (20–30 ft)**	**9–12 m (30–40 ft)**	**12–15 m (40–50 ft)**	**>15 m (> 50 ft)**
15–30 cm (6–12 in)					
31–60 cm (12–24 in)					
61–90 cm (24–36 in)					
>90 cm (>36 in)					

5. **LWD Jams.** Jams are defined as groups of qualifying LWD that span the channel and contain greater than five pieces, where individual pieces are touching at least 1 other qualifying piece. Estimate the dimensions of each jam (length, width and height), photograph the jam, and place the jam in one of the following bins: 5–10 pieces, 10–50 pieces, 50–100 pieces, and >100 pieces. To allow quantification of LWD frequency and volume by study reach, all qualifying pieces found within jams should also be tallied for each habitat unit as described above

Analytical methods

To calculate the volume of LWD, assign the midpoint of each length and diameter bin to each piece of LWD in that bin (for instance for LWD 6–12 inches in diameter and 10–20 feet long, all individual pieces were assumed to be 9 inches in diameter and 15 feet long). This methodology should result in a close approximation of the actual volume of LWD present. However, because of the estimation, the final volume should nonetheless be considered more a relative volume (illustrating the differences between reaches) than an absolute volume.

Key pieces of LWD are defined by the Forest Service interim Riparian Management Objectives (RMOs) for areas east of the Cascade crest in Washington, Oregon and Idaho as greater than 35 feet in length and greater than 12 inches in diameter. In order to be an effective key piece of LWD, the LWD must be at least as long as the bankfull width. The average bankfull width in all subwatersheds was less than 35 feet. Using this protocol, LWD is tallied into length bins of 10–20, 21–30, 31–40, 41–50 and >50 feet in length. To estimate the number of key pieces, it is assumed that 40% of all pieces of LWD in the 31–40 foot length bin (>12 inches in diameter) were >35 feet long. The resulting estimate was added to all pieces in the 41–50 and >50 foot length bins that were >12 inches in diameter to calculate the total number of key pieces.

To more precisely estimate key pieces for future monitoring, length bins should be modified such that one bin begins with pieces 35 feet in length.

2.2.3.5 Spawning gravel abundance

Quantity and quality of suitable spawning habitat for resident trout and anadromous salmonids (steelhead and spring Chinook salmon) in each habitat unit was be estimated as described in the steps below.

Step-by-step instructions

1. For each habitat unit visually assess suitable habitat patches for resident and anadromous salmonids based on suitable gravel size criteria and minimum patch size criteria (Table 5).

Table 5. Gravel size and minimum patch size criteria for resident trout and salmon and steelhead used for delineation of suitable spawning habitat.

Resident trout			Spring Chinook salmon and steelhead		
Gravel size		Minimum patch size	Gravel size		Minimum patch size (diameter)
Suitable	Optimum		Suitable	Optimum	
6–64 mm (0.2–2.5 in)	13–38 mm (0.5–1.5 in)	1 ft. in diameter	10–100 mm (0.2–6.0 in)	46-78[1] mm (1.5–4.0 in)	1 meter in diameter

[1] 46 mm is optimum for steelhead, 78 mm is optimum for Chinook.

2. Estimate and record the total suitable spawning habitat area (m^2) for resident and anadromous salmonids within a habitat unit (sum the area of all suitable patches).
    a. For both anadromous salmon and resident gravels, include “dry” patches that appear to have been inundated during typical spring stream flows, if they are well-sorted and in a suitable location for spawning at higher flows. This approach takes into account spawning gravels that are inundated during the spring steelhead spawning season through egg incubation period. When dry patches are included in suitable area estimates, indicate the percentage of the spawning gravel that dry versus wet.
4. Count and record the number of patches that are suitable for both anadromous and resident within a habitat unit (to allow calculation of mean patch size from total suitable area).
5. Visually estimate the average percent embeddedness of the dominant particles in spawning habitat patches within each unit based on the criteria in Table 6.
6. Rate the overall condition (quality) of the spawning habitat present in each habitat unit by species as *Good*, *Fair*, or *Poor*, taking into account gravel size, water depth and velocity, embeddedness, and presence and proximity of escape cover / resting habitat. Table 6 provides guidelines for these ratings.

Table 6. Guidelines for qualitative ratings of spawning habitat condition.

Spawning habitat attribute	Good	Fair	Poor
Gravel size	Optimum for the species (Table 5)	Intermediate between good and poor	Marginal for the species
Gravel shape and sorting	Well sorted and rounded	Intermediate between good and poor	Poorly sorted and/or angular
Water depth	Estimated depth during spawning period >1.0 ft for anadromous species and >0.5 ft for resident trout	Intermediate between good and poor	Estimated depth during spawning period <0.8 ft for anadromous species and <0.3 ft for resident trout or gravels partially exposed to air
Water velocity	Moderate surface velocities, estimated to be 0.2–0.6 m /s (0.7–2.0 f/s) during spawning period	Intermediate between good and poor	Excessively slow [<0.2 m/s (0.7 f/s)] or fast [<1.0 m/s (3.3 f/s)] surface velocities during spawning period
Substrate embeddedness	<30%	30–50%	>50%
Escape Cover	Within ~30.5 m (100 ft) of pool with sufficient depth [> 0.6 m (2.0 ft)] and cover (e.g., undercut bank, boulders, or wood) to escape from predators and rest	Intermediate between good and poor	Little or no escape cover nearby

2.2.3.6 Habitat unit comments

Record field pertinent ecological observations such as beaver activity, presence of freshwater mussels or amphibians, notable vegetation, presence of redds, wildlife observed, or streambank disturbance.

2.2.3.7 GPS data

GPS points should be collected at all study reach breaks, all transects, all snorkeled pools, and at all unique features (major tributary junctions, LWD jams, potential barriers, culverts, significant and unique spawning areas, etc…). Record waypoints in specified locations in GeoOptix or on datasheets.

2.3 Long-term Monitoring Station Establishment and Data Collection

Two monitoring stations consisting of 152 m (500 ft) of channel were established: one in the Lower mainstem Clear Creek at the National Forest boundary and one in West Fork Clear Creek near its confluence with Clear Creek. Each station was permanently monumented, photographed, and documented with GPS points.

The variables evaluated at each monitoring station included stream channel physiography, stream discharge, air and water temperatures, stream bed surface substrate, cobble embeddedness, snorkeling and fish abundance according to the procedures described in the sections that follow.

2.3.1 Stream channel physiography

After determining and monumenting the upper and lower boundaries of each monitoring station, longitudinal profiles of channel elevation were surveyed. Elevations of key points along three cross-sections were also surveyed. Monitoring stations were set up and surveyed using procedures outlined in Harrelson et al. (1994). The following step-by-step instructions are a condensed version; refer to Harrelson et al. (1994) for more detailed instructions.

Step-by-step instructions

1. **Layout the longitudinal profile and monument each end.** Each monitoring station should had a 500 foot long thalweg/longitudinal profile. The endpoints of the thalweg/longitudinal profile were monumented with rebar driven into the bank, far enough back from the wetted width that it will be unlikely to be disturbed by high flow events. These endpoints was also be marked in a nearby tree (that appears strong and healthy) with both brightly colored flagging and more permanent aluminum tags. The ends of the profile were photographed and locations marked with GPS.
2. **Layout the cross-sections and monument each end.** Within the 500 ft monitoring station, field crews established three (3) monumented cross-sections spaced 100-feet apart (measured at the thalweg). The cross-sections were at the 100 ft, 200 ft and 300 ft points from the downstream end of the station. The ends of each cross-section were monumented with rebar driven into the bank above the floodprone level, or on a high terrace (if present) and marked with flagging and aluminum tag.
3. **Establish the survey benchmark**. The benchmark is the initial reference (or starting) point of the survey. The benchmark should be located outside the channel (and floodplain, if possible), yet near enough to be clearly visible. The best placement is on a permanent natural feature of the site, such as an outcropping of bedrock, or the highest point of a large boulder. A large, embedded boulder with a single high point on the low stream terrace is ideal. In the absence of a boulder, a benchmark should be established using a four-foot length of rebar driven into the ground. The benchmark should be photographed, and a GPS point taken. The elevation of the benchmark should be set at an arbitrary height of 100.00 ft.
4. **Set up the auto-level** so that the benchmark and (ideally) all of the long profile is visible. The best locations are usually on the low stream terrace, because it is stable and close enough to the water surface that rod extensions are minimized. Consider setting up in the stream channel if visibility is limited and if the depth and bottom conditions make this feasible (the stream bottom should be stable and the level must not get wet). Shoot the benchmark to determine the height of the instrument.
5. **Conduct the longitudinal survey**. Survey the thalweg of the creek from the downstream to the upstream end. Shoot elevations to capture stream morphology. When the stream bed is uniform, shoot an elevation at intervals at least as close together as the average wetted width. Shoot elevations at all notable channel features, including such things as pool tails, pool maximum depths, riffle crests, etc. Record the total distance from the start point and the elevation for each interval.
6. **Conduct the cross-section surveys**. At a minimum, shoot elevations at the high terrace, low terrace (if present) flood prone height, bankfull stage, water’s edge, and thalweg. Once in the channel, shoot elevations at a regular interval (basically, either channel width divided by 20, or 1 or 2 foot intervals are commonly used) with additional shots to capture features such as breaks in slope. Avoid the tops of isolated boulders and logs (or shoot at

close intervals to accurately record large ones). Record the total distance from the start point and the elevation for each interval.

2.3.2 Stream discharge

Stream discharge was measured twice at one location within each monitoring station. Stream discharge was measured and calculated with the procedures described below.

Step-by-step instructions

1. Select suitable location. Locate a cross-section of the stream channel for discharge measurement that has most of the following qualities: (a laminar pool tail or glide area with a U-shaped channel cross-section that is free of obstructions provides the best conditions for measuring discharge. do not measure discharge in a pool.)
    a. Segment of stream above and below the selected cross-section is straight.
    b. Depths are mostly greater than 15 cm, and velocities are mostly greater than 0.15 m/s.
    c. "U" shaped, with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
    d. Flow is relatively uniform, with no eddies, backwaters, or excessive turbulence.
2. Stretch and secure a measuring tape across the stream perpendicular to flow, with the “zero” end on the left bank. See figure 13.
3. Check to ensure the velocity meter is functioning properly and calibrated.
4. Divide the total wetted stream width into 15 to 20 equally sized intervals. To determine interval width, divide the width by 20 and round up to a convenient number. Intervals should not be less than 10 cm wide, even if this results in less than 15 intervals. Take the first measurement at one interval out from the left bank.
5. Stand downstream of the velocity meter when taking measurements.
6. Place a graduated depth rod in the stream at the interval point and record the water depth indicated.
7. Slide the velocity probe down the depth rod so that the bottom of the rod is at 0.6 of the measured depth below the surface of the water. Face the probe upstream at a right angle to the cross-section, even if local flow eddies hit at oblique angles to the cross-section.
8. Wait 20 seconds to allow the meter to equilibrate, and then measure. Use the Fixed Point Averaging (FPA) feature on the flow meter and set the period to 30 seconds. Record the velocity.
9. Move to the next interval point and repeat steps 6 through 8. Continue until depth and velocity measurements have been recorded for all intervals.

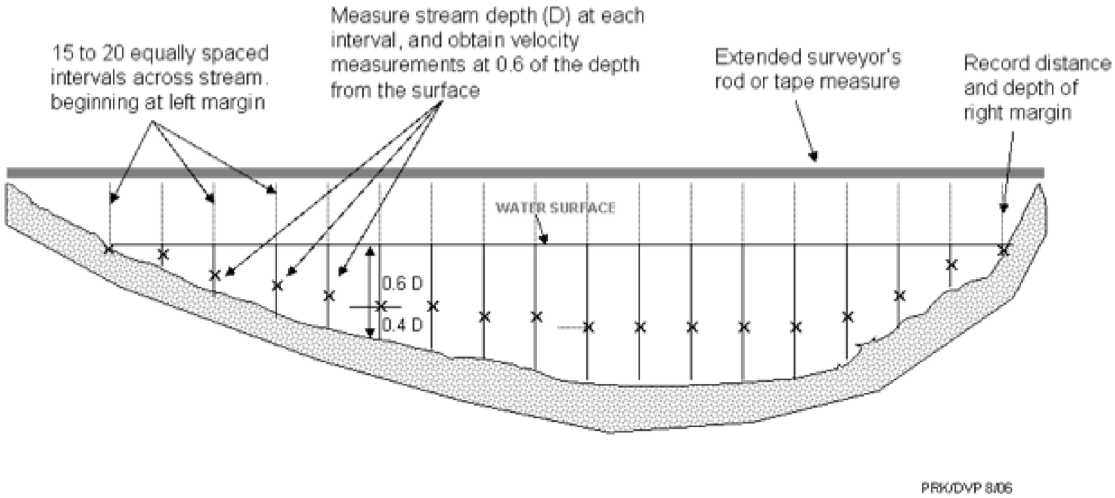

Figure 13. Procedure for measuring stream discharge.

2.3.3 Stream bed surface substrate

Bed surface substrate is measured using a modified Wolman Pebble Count procedure described in Harrelson, et al. (1994). The modifications are as follows:

- Pebbles are measured in a zig-zag pattern, starting at the downstream end of the longitudinal reach, and continuing to the upstream end of the monumented thalweg/longitudinal profile.
- Measurements of the medial axis are measured and recorded to the nearest millimeter; not tallied into Wentworth phi-classes.
- A minimum of 300 particles are measured at each station.

Additional detail can be found in Harrelson et al. (1994).

2.3.4 Cobble embeddedness

Cobble embeddedness was measured using the methods of Skille and King (1989). At each of the three stream channel cross-sections, a 60 cm hoop was placed at 25%, 50%, and 75% distances within the cross-section wetted-width (for a total of 9 measurements at each monitoring station). The estimated percentage of embeddedness (based on discoloration or stain lines) were recorded for all surface particles between 45 mm and 300 mm in diameter that were located at least 50% within the hoop.

Analytical methods

Cobble embeddedness was analyzed based on methods in Burton and Harvey (1990).

Percent embeddedness (E) of particles within the hoop is calculated using the formula:

$$E=d_2/d_1(100)$$

Where d_1 is the total vertical rock length, and d_2 is the vertical depth of the particle below the plane of embeddedness.

Weighted embeddedness, a metric that takes into account the percentage of the hoop covered entirely by fine sediments (this area is considered 100% embedded), was also be estimated using the following formula:

$$\text{Weighted embeddedness} = \frac{(\%\text{ hoop area in fines} \times 100) + (\%\text{ hoop area not in fines} \times E)}{100}$$

2.3.5 Temperature

Two continuously recording thermographs were placed at each monitoring station: one completely submerged in the stream channel recording water temperature and one in a nearby upland area recording air temperature.

Stream temperatures will be recorded at least through the summer months May thru September; but may be recorded year-round.

2.3.6 Fish abundance (electrofishing)

Fish abundance was evaluated at each monitoring station using electrofishing. Prior to electrofishing, at least one pool in the monitoring station reach was first be snorkeled to help calibrate snorkel counts to electrofishing results. The snorkeled pool was isolated with block nets and electrofished separately from the rest of the 500 foot reach. The snorkeling protocol was the same as that outlined in Section 2.1.3 above.

Removal electrofishing was conducted following procedures based on Hankin and Reeves (modified 1988).The removal method is based upon the theory that a segment of stream can be fished two or more times to attempt to remove all of the fish and obtain a total count. Because some fish are successful in avoiding capture, a total count cannot normally be obtained. However, a regression equation can be developed that will estimate, with known accuracy and precision, the total number of fish in the sampled reach.

Specific electrofishing procedures are described below.

Step-by-step instructions

1. Block nets were placed at the upstream and downstream end of the 500 ft sample reach in order to reduce escapement of fish from the sample area.
2. Using a backpack electrofisher with settings adjusted for maximum efficiency given local conditions (e.g., conductivity of the water), the entire sample reach was thoroughly electrofished, starting at the downstream end and ending at the upstream end
3. All stunned fish and all fish discovered in downstream block net were captured and placed in buckets with cool water or net pens for processing.
4. Fish captured in each pass were identified to species, enumerated, and measured (fork length in mm).
5. Steps 2 through 4 was repeated two more times, for a total of three passes, to improve accuracy of estimates.
6. A fourth pass was conducted if either of the following occurred:

   a. Zero fish were collected on the third pass
   b. The number of fish capture on the third pass was less than 10% of the number captured on the second pass.
7. For larger and wider channels, two backpack electrofishers were be used, each followed by at least one crew member with a long handled dip net and bucket to collect captured fish. The other two crew members were stationed on the bank to process captured fish while the remaining passes were completed.

Analytical methods

O. mykiss populations were estimated using the Zippin methodology described by Platts et al. (1983) for each of the monitoring stations. Separate estimates were made for the population as a whole, (including age-0 fish; <90 mm), age-1 and older fish (90 mm and longer), and age-2 and older fish (150 mm and longer). Too few fish of other species were captured at most sites to allow for population estimates to be conducted. Length at age cutoffs were established based on a cluster analysis of length frequencies.

3 EQUIPMENT LIST

Reach and habitat unit-scale surveys

	Hard Copy Maps		Axe / Pulaski (in field vehicle)
	Field Identification Guides (Trees And Fish)		Shovel (in field vehicle)
	Camera		Lighter/matches
	Clinometer		
	Clipboards		Depth Staff (stadia rod)
	Compass		Polarized Sunglasses
	Handheld GPS unit		Waders
	iPad, extra battery		Wading boots & neoprene booties
			Raingear
	Data Forms		Headlamp, Whistle
	Fiberglass Measuring Tape		Water Jug
	Field Book		Sunscreen
	Flagging Tape		Diameter tape for LWD
	Survey Methods And Instructions		Wet suit / dry suit
	Harrelson (1994) protocols		Masks and snorkels
	Pocket Thermometer		Dive slate (PVC cuff w/pencil)
	Vests		Ruler (mm)
	Satellite phone and cell phone		Polarized Sunglasses
	Laser Range-Finder		Waders
	Pencils, Sharpie Waterproof Marker		Tent, Sleeping Bag, Stove, Food, Utensils, and Other Camping Gear
	First Aid Kits		Vehicle Safety Equipment (Flares, Jumper Cables, Fire Extinguisher)

Long-term Monitoring stations

	Hard Copy Maps and data forms		Block nets and wood dowels
	Field Identification Guides (Trees And Fish)		Dip nets
	Camera		Buckets and aquarium nets
	Total station or engineers level and tripod		Measuring board
	Surveyor's staff		Digital scale
	iPad, extra battery		MS-222
	Laser Range-Finder		Wet suit
	Pencils, Sharpie Waterproof Marker		Masks and snorkels
	Satellite phone		Dive slate (PVC cuff w/pencil)
	First Aid Kits		Velocity meter
	Cell Phone		Ruler (mm)
	Waders and boots		60 cm hoop
	Polarized Sunglasses		Rebar / end caps and sledge hammer
	Water jug		Flagging & aluminum tags for start and end points
	Electrofishers (2)		Thermographs, protective housing, and cable for deployment
	Spare electrofisher batteries (2)		Vehicle Safety Equipment (Flares, Jumper Cables, Fire Extinguisher)

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Appendix C

Measured Reach Lengths

Table C-1. Reach identification, characteristics, and length based on field measurements (main channel only; side channel length not included) for high priority streams in the Clear Creek National Forest study area.[1]

Reach ID	Drainage area (km^2)	Gradient (%)	Length (m)
1	Over 100	1–4	920
2	Over 100	1-4	678
3	25–100	1–4	259
4	25–100	4–8	885
5	25–100	1–4	1,572
6	25–100	4–8	786
7	25–100	1–4	2,213
8	25–100	4–8	414
9	25–100	1–4	2,034
10	25–100	1–4	1,206
11	25–100	4–8	278
12	25–100	8–20	482
13	25–100	4–8	311
14	25–100	1–4	486
15	25–100	4–8	1,220
16	25–100	1–4	848
17	25–100	4–8	1,112
18	25–100	1–4	809
19	25–100	4–8	448
20	25–100	1–4	1,423
21	25–100	4–8	196
22	25–100	1–4	164
23	25–100	4–8	618
24	5–25	4–8	249
25	5–25	8–20	891
26	5–25	4–8	252
27	5–25	8–20	382
28	5–25	8–20	502
29	5–25	Over 20	161
30	5–25	4–8	1,443
31	5–25	1–4	829
32	5–25	1–4	784
33	5–25	4–8	217
34	5–25	1–4	269
35	5–25	4–8	2,812
36	5–25	8–20	445
37	5–25	4–8	901
38	5–25	1–4	541
39	5–25	4–8	197
40	5–25	1–4	275
41	5–25	4–8	1,851
42	5–25	8–20	839
43	5–25	4–8	272
44	5–25	8–20	243
45	5–25	4–8	707
46	5–25	4–8	1,258
47	5–25	1–4	967
48	5–25	4–8	1,843

Reach ID	Drainage area (km^2)	Gradient (%)	Length (m)
49	0–5	8–20	691
50	0–5	4–8	734
51	0–5	4–8	753
52	0–5	1–4	183
Total length			**40,104**

[1] Reach lengths included in this appendix are main channel lengths only, as measured in the field. Thus they differ somewhat from the GIS-based stream lengths included in Appendix A.

Table C-2. Reach identification, channel type characteristics, and length (main channel only, as measured in the field) for reaches surveyed on private land downstream of the national forest boundary.

Reach ID	Drainage area (km^2)	Gradient (%)	Length (m)
53	Over 100	1–4%	825
54	Over 100	1–4%	571
55	Over 100	1–4%	511
56	Over 100	1–4%	888
57	Over 100	1–4%	2,579
58	Over 100	1–4%	1,430
Total length			6,804

Appendix D

Riparian Transect Data

Table D-1. Riparian transect data.

Site name	Transect ID	Left bank dominant vegetation (cm) [1]	Left bank sub dominant size (cm)	Left bank sub dominant vegetation	Right bank sub dominant size (cm)	Right bank sub dominant vegetation	Left Bank riparian canopy closure (%)	Right bank dominant vegetation (%)	Left bank dominant size (cm)	Right bank dominant size (cm)	Left bank surface type [2]	Right bank surface type	Left bank slope (%)	Right bank slope (%)	Left bank shrub cover (%)	Right bank shrub cover (%)
01	1	DD	0–3	PG	3–15	MC/D	14	S	3–15	0–3	H	H	29	29	10	50
01	2	S	0–3	PG	0–3	PG	17	S	3–15	3–15	LT	F	5	5	100	70
02	1	DD	0–3	S	0–3	PG	2	DD	3–15	3–15	LT	H	7	18	45	15
03	1	DD	0–3	S	3–15	S	17	PG	3–15	0–3	LT	H	8	15	40	20
04	2	S	0–3	PG	3–15	S	14	PG	3–15	0–3	H	H	45	48	60	15
05	1	S	0–3	PG	3–15	S	13	MC/D	3–15	15–30	LT	LT	8	7	75	45
05	2	MC/D	0–3	S	0–3	PG	7	S	15–30	0–3	H	H	46	6	25	55
05	3	S	3–15	MC/D	0–3	PG	12	C	0–3	15–30	LT	LT	9	8	65	15
06	1	MC/D	3–15	S	3–15	S	16	DD	15–30	3–15	F	H	10	44	50	75
07	1	C	3–15	C	30–50	C	17	AG	15–30	0–3	H	LT	45	2	40	10
07	2	S	30–50	C	15–30	DD	12	C	3–15	30–50	H	H	7	14	90	35
07	3	DD	3–15	S	3–15	S	15	C	3–15	15–30	H	H	45	30	70	60
07	4	DD	3–15	S	0–3	S	9	DD	3–15	3–15	F	F	2	2	85	90
08	2	S	0–3	PG	3–15	S	11	C	3–15	50–90	H	H	90	25	83	65
09	1	C	15–30	DD	15–30	S	17	C	50–90	50–90	H	H	35	20	35	60
09	2	C	3–15	S	3–15	S	16	C	50–90	50–90	H	H	30	45	45	15
09	3	C	0–3	S	0–3	PG	17	S	> 90	0–3	H	LT	35	10	70	90
09	4	C	0–3	S	0–3	S	17	C	> 90	> 90	H	H	40	35	50	40
10	1	C	0–3	PG	3–15	DD	14	C	> 90	50–90	H	H	25	45	20	70
10	2	DD	3–15	S	3–15	S	12	DD	30–50	15–30	LT	LT	2	2	85	90
11	1	S	0–3	PG	0–3	S	13	MC/D	3–15	15–30	LT	H	6	42	55	30
12	1	MC/D	0–3	S	0–3	S	12	MC/D	15–30	15–30	H	H	6	21	40	35

Site name	Transect ID	Left bank dominant vegetation (cm)[1]	Left bank sub dominant size (cm)	Left bank sub dominant vegetation	Right bank sub dominant size (cm)	Right bank sub dominant vegetation	Left Bank riparian canopy closure (%)	Right bank dominant vegetation (%)	Left bank dominant size (cm)	Right bank dominant size (cm)	Left bank surface type[2]	Right bank surface type	Left bank slope (%)	Right bank slope (%)	Left bank shrub cover (%)	Right bank shrub cover (%)
13	1	MC/D	0–3	PG	0–3	S	16	MC/D	15–30	30–50	H	H	26	19	25	45
14	1	S	3–15	DD	0–3	PG	14	S	0–3	0–3	H	H	35	16	70	30
15	1	DD	0–3	S	0–3	PG	16	S	15–30	3–15	HT	H	20	32	30	75
16	1	S	0–3	PG	0–3	S	2	C	3–15	30–50	F	RR	1	36	75	75
17	1	S	3–15	MC/D	0–3	S	15	MC/D	0–3	3–15	F	H	0	25	75	80
17	2	C	3–15	DD	3–15	DD	16	C	30–50	15–30	H	HT	32	14	25	75
18	1	MC/D	0–3	S	3–15	S	9	C	15–30	50–90	H	F	29	2	50	90
19	1	C	3–15	S	0–3	PG	12	S	50–90	3–15	H	H	25	33	80	90
20	1	S	0–3	PG	3–15	DD	10	S	3–15	3–15	LT	H	7	41	75	90
20	2	MC/D	0–3	S	0–3	PG	13	S	3–15	3–15	LT	H	10	45	100	70
20	3	MC/D	0–3	S	3–15	S	17	MC/D	15–30	15–30	H	F	80	4	50	100
21	1	DD	0–3	S	3–15	S	15	MC/D	3–15	3–15	HT	H	10	35	80	80
22	1	C	0–3	S	15–30	MC/D	6	S	30–50	3–15	H	H	30	14	40	75
23	1	MC/D	3–15	S	0–3	PG	17	MC/D	15–30	15–30	H	H	20	29	35	20
24	1	C	0–3	PG	0–3	S	17	MC/D	15–30	30–50	H	SC	27	1	20	45
25	1	C	0–3	S	15–30	C	17	PG	15–30	0–3	H	H	39	26	25	25
25	2	C	0–3	PG	3–15	S	17	C	30–50	30–50	H	H	32	13	0	35
26	1	C	0–3	PG	3–15	S	17	MC/D	15–30	15–30	H	H	35	30	5	35
27	1	MC/D	0–3	S	0–3	PG	17	MC/D	15–30	15–30	LT	H	2	37	30	20
28	1	MC/D	0–3	PG	0–3	PG	17	C	15–30	> 90	H	LT	28	0	0	0
29	1	C	0–3	PG	3–15	S	17	C	30–50	30–50	H	H	32	28	0	85
30	1	MC/D	0–3	S	0–3	S	16	DD	3–15	3–15	H	F	23	1	45	40
30	2	S	3–15	DD	0–3	PG	12	S	0–3	0–3	H	H	24	30	60	75
31	1	C	0–3	PG	3–15	S	17	DD	15–30	3–15	H	LT	29	11	15	45

Site name	Transect ID	Left bank dominant vegetation (cm)[1]	Left bank sub dominant size (cm)	Left bank sub dominant vegetation	Right bank sub dominant size (cm)	Right bank sub dominant vegetation	Left Bank riparian canopy closure (%)	Right bank dominant vegetation (%)	Left bank dominant size (cm)	Right bank dominant size (cm)	Left bank surface type[2]	Right bank surface type	Left bank slope (%)	Right bank slope (%)	Left bank shrub cover (%)	Right bank shrub cover (%)
31	2	C	0–3	PG	0–3	PG	14	C	50–90	50–90	H	LT	13	4	10	10
32	1	C	3–15	PG	3–15	S	16	DD	50–90	15–30	H	H	40	40	25	57
33	1	C	3–15	S	0–3	PG	17	S	50–90	3–15	H	LT	45	15	85	90
34	1	DD	3–15	S	3–15	S	5	DD	15–30	3–15	F	F	0	0	75	90
35	1	C	0–3	PG	15–30	DD	17	C	50–90	50–90	H	LT	25	5	20	75
35	1	C	0–3	PG	0–3	PG	17	C	> 90	> 90	HT	H	10	48	5	1
35	1	C	0–3	PG	0–3	PG	15	C	50–90	50–90	H	H	40	35	0	0
35	2	C	0–3	PG	0–3	PG	16	C	> 90	> 90	H	LT	45	30	0	0
35	2	C	0–3	PG	0–3	PG	16	C	50–90	30–50	H	H	30	44	5	5
36	1	C	0–3	PG	0–3	S	15	C	> 90	> 90	H	H	50	35	10	30
37	1	DD	3–15	S	0–3	PG	14	S	15–30	3–15	H	H	25	27	90	55
38	1	C	15–30	DD	0–3	PG	15	MC/D	50–90	3–15	F	F	20	20	30	25
39	1	C	3–15	DD	0–3	S	15	MC/D	> 90	15–30	F	H	6	32	25	50
40	1	PG	3–15	S	30–50	C	9	S	0–3	0–3	F	H	1	33	50	90
41	1	C	0–3	PG	0–3	PG	16	C	50–90	50–90	F	H	3	35	20	25
41	2	C	> 90	PG	0–3	PG	16	C	50–90	50–90	H	LT	26	7	5	5
41	3	C	0–3	PG	0–3	PG	16	C	> 90	50–90	F	H	4	39	10	25
42	1	C	0–3	PG	3–15	S	17	C	50–90	50–90	H	H	30	29	20	40
43	1	PG	3–15	DD	15–30	DD	10	PG	0–3	0–3	F	F	6	2	10	5
44	1	C	3–15	S	0–3	S	17	MC/D	50–90	0–3	H	H	38	16	50	25
45	1	C	0–3	PG	0–3	NV	17	MC/D	30–50	30–50	H	H	25	35	5	80
46	1	C	0–3	PG	0–3	PG	17	C	50–90	50–90	H	LT	32	8	5	5
46	2	C	0–3	PG	0–3	PG	16	C	50–90	30–50	H	H	39	28	10	10
47	1	PG	3–15	C	0–3	PG	16	C	0–3	50–90	F	LT	9	1	5	5

Site name	Transect ID	Left bank dominant vegetation (cm)[1]	Left bank sub dominant size (cm)	Left bank sub dominant vegetation	Right bank sub dominant size (cm)	Right bank sub dominant vegetation	Left Bank riparian canopy closure (%)	Right bank dominant vegetation (%)	Left bank dominant size (cm)	Right bank dominant size (cm)	Left bank surface type[2]	Right bank surface type	Left bank slope (%)	Right bank slope (%)	Left bank shrub cover (%)	Right bank shrub cover (%)
47	2	C	0–3	S	0–3	PG	16	C	30–50	30–50	H	LT	38	2	40	5
48	1	S	30–50	C	3–15	S	15	PG	0–3	0–3	H	F	33	4	30	30
48	2	C	0–3	PG	0–3	PG	17	DD	15–30	30–50	H	LT	30	6	20	5
48	3	C	3–15	S	3–15	S	15	C	15–30	50–90	H	H	24	22	15	35
49	1	DD	0–3	S	0–3	DD	16	C	3–15	> 90	LT	H	15	20	70	75
50	1	DD	0–3	S	0–3	S	17	DD	3–15	3–15	F	LT	3	17	75	75
51	1	DD	0–3	S	0–3	S	6	DD	15–30	15–30	F	LT	3	5	50	50
52	1	C	0–3	PG	0–3	S	17	DD	50–90	3–15	HT	F	9	4	10	60
53	1	DD	3–15	S	0–3	AG	17	AG	30–50	0–3	RR	RR	0	7	20	10
54	1	MC/D	0–3	S	15–30	DD	14	PG	15–30	0–3	F	F	13	13	40	0
55	1	PG	3–15	DD	3–15	DD	0	PG	0–3	0–3	LT	F	8	2	0	0
56	1	S	0–3	PG	15–30	DD	13	PG	3–15	0–3	F	F	9	3	90	0
57	1	DD	3–15	PG	3–15	PG	17	C	15–30	15–30	LT	LT	2	1	75	25
57	1	NV	0–3	NV	0–3	NV	0	NV	0–3	0–3	F	F	0	0	0	0
57	1	NV	0–3	NV	0–3	NV	0	NV	0–3	0–3	F	F	0	0	0	0
58	1	DD	0–3	S	3–15	S	11	DD	3–15	3–15	LT	H	5	42	70	50
58	1	NV	0–3	NV	0–3	NV	0	NV	0–3	0–3	F	F	0	0	0	0

[1] DD: Deciduous Dominated; S: Shrubs; MC/D: Mixed Conifer/Deciduous; C: Coniferous; PG: Perennial Grasses; NV: No Vegetation; AG: Annual Grasses
[2] pH: Hillslope; F: Floodplain; LT: Low Terrace; HT: High Terrace; RR: Rip Rap; SC: Side Channel

Appendix E

Assessment of Potential Fish Passage Barriers

Table E-1. Potential barriers to fish migration documented during 2015 surveys of high priority stream reaches in the Clear Creek study area, along with GPS coordinates and site-specific measurements.

Potential barrier ID	Stream meter[1]	Coordinates (UTM Zone 11T)	Barrier type/s	Jump height (m)	Jump distance (m)	Jump pool depth (m)	Depth at crest (m)	Salmonid species documented upstream[2]	Barrier designation
Clear Creek									
6.1	4,590	593782.08 5100320.93	Physical, hydraulic	0.9	2.35	1.03	0.35	CS, OM, CTT	Seasonal barrier—low
35.1	13,175	599920.93 5101635.12	Physical, hydraulic	1.4	3.3	0.35	0.18	CTT	Seasonal barrier—high
36.1	15,085	601146.09 5102088.68	Physical, hydraulic	1.3	1.7	0.6	0.12	CTT	Seasonal barrier—high
36.2	15,098	601171.4 5102073.77	Physical, hydraulic	1	0.45	0.24	0.18	CTT	Seasonal barrier—high
36.3	15,128	601151.94 5102038.65	Physical, hydraulic	0.9	0.3	0.4	0.07	CTT	Seasonal barrier—moderate
36.4	15,365	601199.17 5101848.28	Physical, hydraulic	n/a[3]	n/a	n/a	n/a	CTT	Seasonal barrier—high
36.5	15,383	601189.13 5101837.67	Physical, hydraulic	1.1	1.4	0.26	0.01	CTT	Likely total barrier
36.6	15,437	601189.91 5101786.11	Hydraulic	n/a	n/a	n/a	n/a	CTT	Seasonal barrier—high
"Tailed Frog Creek"									
49.1	76	601678.61 5101159.46	Physical, hydraulic	2.7	2.3	0.23	0.06	None	Likely total barrier
49.2	95	601697.21 5101162.55	Physical, hydraulic	2.4	2.5	0.28	0.1	None	Likely total barrier
49.3	102	601697.21 5101162.55	Physical, hydraulic	1.2	0.6	0.41	0.07	None	Seasonal barrier—low

Potential barrier ID	Stream meter[1]	Coordinates (UTM Zone 11T)	Barrier type/s	Jump height (m)	Jump distance (m)	Jump pool depth (m)	Depth at crest (m)	Salmonid species documented upstream[2]	Barrier designation
West Fork Clear Creek									
12.1	645	591069.1 5098938.95	Physical	1.75	1.5	0.65	0.2	OM, CTT	Seasonal barrier—high
25.1	1,422	591201.62 5098263.12	Physical, hydraulic	1.6	2.5	0.3	0.2	OM, CTT	Seasonal barrier—high
27.1	2,626	591249.99 5097118.97	Physical	1.5	2	0.2	0.15	OM, CTT	Seasonal barrier—high
27.2	2,722	591225.49 5097027.15	Physical	1.2	1.3	0.66	0.2	OM, CTT	Seasonal barrier—low
27.3	2,731	591225.49 5097027.15	Physical	1.5	2.8	0.25	0.1	OM, CTT	Seasonal barrier—moderate
Lost Mule Creek									
29.1	613	591729.24 5098209.06	Physical, hydraulic	3	1.4	0.09	0.09	None	Likely total barrier
South Fork Clear Creek									
15.1	1,245	592427.37 5099028.42	Physical	1.2	2.2	0.84	0.3	CS, OM	Seasonal barrier—low
15.2	1,337	592500.92 5099027.2	Physical	1.2	2.8	0.65	0.5	CS, OM	Seasonal barrier—moderate
15.3	1,586	592726.11 5099029.02	Physical	1.3	2.1	0.75	0.35	CS, OM	Seasonal barrier—moderate
15.4	1,636	592760.73 5099016.99	Physical	1.1	1.5	1.2	0.25	CS, OM	Seasonal barrier—low
15.5	1,663	592786.29 5099015.59	Physical	2	2.7	1.2	0.6	CS, OM	Seasonal barrier—high
17.1	3,196	594055.92 5098664.78	Physical	1.6	1.7	0.5	0.35	OM	Seasonal barrier – high[4]
19.1	4,554	595034.49 5097892.76	Physical	1.4	1.5	0.82	0.31	OM	Seasonal barrier—low

Potential barrier ID	Stream meter[1]	Coordinates (UTM Zone 11T)	Barrier type/s	Jump height (m)	Jump distance (m)	Jump pool depth (m)	Depth at crest (m)	Salmonid species documented upstream[2]	Barrier designation
Pine Knob Creek									
48.1	2,979	598833.62 5103888.3	Physical	1.3	2	1.15	0.07	OM	Seasonal barrier—high
Browns Spring Creek									
42.1	3,627	601150.44 5102666.12	Physical	1.5	2	0.52	0.2	CTT	Seasonal barrier—low
44.1	4,135	601558.8 5102502.25	Physical, hydraulic	1.6	1.2	0.5	0.1	CTT	Seasonal barrier—high
44.2	4,211	601618.7 5102500.9	Physical, hydraulic	n/a	n/a	n/a	n/a	CTT	Likely total barrier

1 Stream meters listed are from the confluence with the mainstem, except for mainstem Clear Creek, which starts at Reach 1 near the USFS Boundary.
2 CS = Chinook salmon, OM = steelhead/rainbow, CTT = cutthroat trout
3 Potential Barrier was too complex to take standard measurements.
4 This Potential Barrier was just upstream of the documented upper distribution to Chinook salmon in the South Fork and therefore may constitute a total barrier to that species.

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Potential Barrier 6.1

This feature may present a seasonal passage obstacle to anadromous salmonids during low flows due to jump distance required to pass and during high flows due to excessive velocities. However, a 0.9 m deep jump pool and the presence of a small, low-velocity depression for resting midway through is expected to facilitate passage at moderate stream flows. Presence of adult Chinook upstream indicate this feature is at most a low-flow passage obstacle.

Photo E-1. Looking upstream at Potential Barrier 6.1, located in Reach 6 of Clear Creek.

Potential Barrier 35.1

This feature consists of two, steep bedrock chutes with shallow, high velocity water and minimal jump pools downstream. At low flows, this site appears to present a total barrier to anadromous fish migration. At higher flows, there is a possible alternative passage route on river left, but water velocities may be too high for passage. This feature marks the documented upstream extent of *O.mykiss* in the mainstem of Clear Creek from 2015 snorkel surveys. Densities of cutthroat trout become much higher upstream of this location.

Photo E-2. Looking upstream at Potential Barrier 35.1, located in Reach 35 of Clear Creek.

Potential Barrier 36.1

This is the first of three potential barriers within a 50 m high-gradient section of Clear Creek. The site, a 7 m long, steep bedrock/boulder cascade has multiple features that could impeded fish passage. On the downstream end, water sheets over a steep bedrock drop, which is expected to prevent fish passage at lower stream flows, but may be passable at moderate stream flows as water depth increases. On the upstream end there is a nearly 1 m high vertical drop that could also prevent passage at low flows due to the shallow jump pool. The site may be passable at moderate flows, but due to the constricted nature of the channel at this location, high water velocities at higher stream flows likely prevent fish passage.

Photo E-3. Looking upstream at Potential Barrier 36.1, located in Reach 36 of Clear Creek.

Potential Barrier 36.2

This is the second of three potential barriers within a 50 m high-gradient section of steam. This feature is within a short cascade and consists of a vertical drop onto boulders. Due to the drop and lack of a jump pool this feature is expected to be a barrier to fish passage at low stream flows. It may be passable at moderate flows via an intermediate jump pool on the right bank, but water velocities may deter fish passage at higher stream flows due to the highly confined and high gradient nature of the channel.

Photo E-4. Looking upstream at Potential Barrier 36.2, located in Reach 36 of Clear Creek.

Potential Barrier 36.3

This is the third of three barriers within a 50 m high-gradient section of steam. This feature may present a seasonal, low-flow barrier due to the orientation of the jump pool in relation to the jump. However, it is expected to be passable at moderate to high stream flows.

Photo E-5. Looking upstream at Potential Barrier 36.3, located in Reach 36 of Clear Creek.

Potential Barrier 36.4

This is the first of three potential barriers within a 75 m high-gradient section of stream and the fourth in Reach 36. The feature is a 7 m long cascade with an overall gradient of 18%. It consists of several high-gradient channels and steep drops cutting across bedrock. Standard measurements were not recorded due to complexity of the site. Small depressions that could be used for holding occur throughout the feature, and therefore fish passage may be possible for some fish at moderate stream flows when ample depth is available to traverse the bedrock. However, this site in combination with similar features just upstream, is likely a considerable obstacle to fish passage and may constitute as a total barrier.

Photo E-6. Looking upstream at Potential Barrier 36.4, located in Reach 36 of Clear Creek.

Potential Barrier 36.5

This is the second of three potential barriers within a 75 m long high-gradient section of stream and the fifth in Reach 35. This feature is an 11 m long falls/cascade consisting of two separate of vertical drops exceeding 1 m, along with water sheeting over bedrock and boulders. Fish passage is expected to be very challenging if not impossible across most stream flows. At low flows water depth and lack of jump pools limit passage. At moderate and high flows water velocities are expected to be too high for passage. In combination with considerable obstacles just downstream and upstream, this site is expected to be a barrier to both resident and anadromous fish.

Photo E-7. Looking upstream at Potential Barrier 36.5, located in Reach 36 of Clear Creek.

Potential Barrier 36.6

This is the third of three potential barriers within a 75 m high-gradient section of stream and the sixth in Reach 36. This feature is a 9 m long, steep bedrock chute that presents a potential barrier due to shallow depths and lack of resting pools at low flows and high water velocities at higher flows. This sites is expected to present a major obstacle to fish passage, if not a total barrier, under most conditions.

Photo E-8. Looking upstream at Potential Barrier 36.6, located in Reach 36 of Clear Creek.

TAILED FROG CREEK

Potential Barrier 49.1

This site is the first of two likely barriers within a 25 m high-gradient section of stream just upstream from the confluence with mainstem Clear Creek. This site is an 11 m long, steep bedrock cascade with a nearly vertical high waterfall at the top that is > 2 m high and lacks a jump pool. The feature also contains several other shorter vertical drops. Based on the combination of physical drops and high water velocities as well as a significant waterfall just upstream, this site is expected to be a total barrier to fish movement. No cutthroat trout were found upstream of this feature.

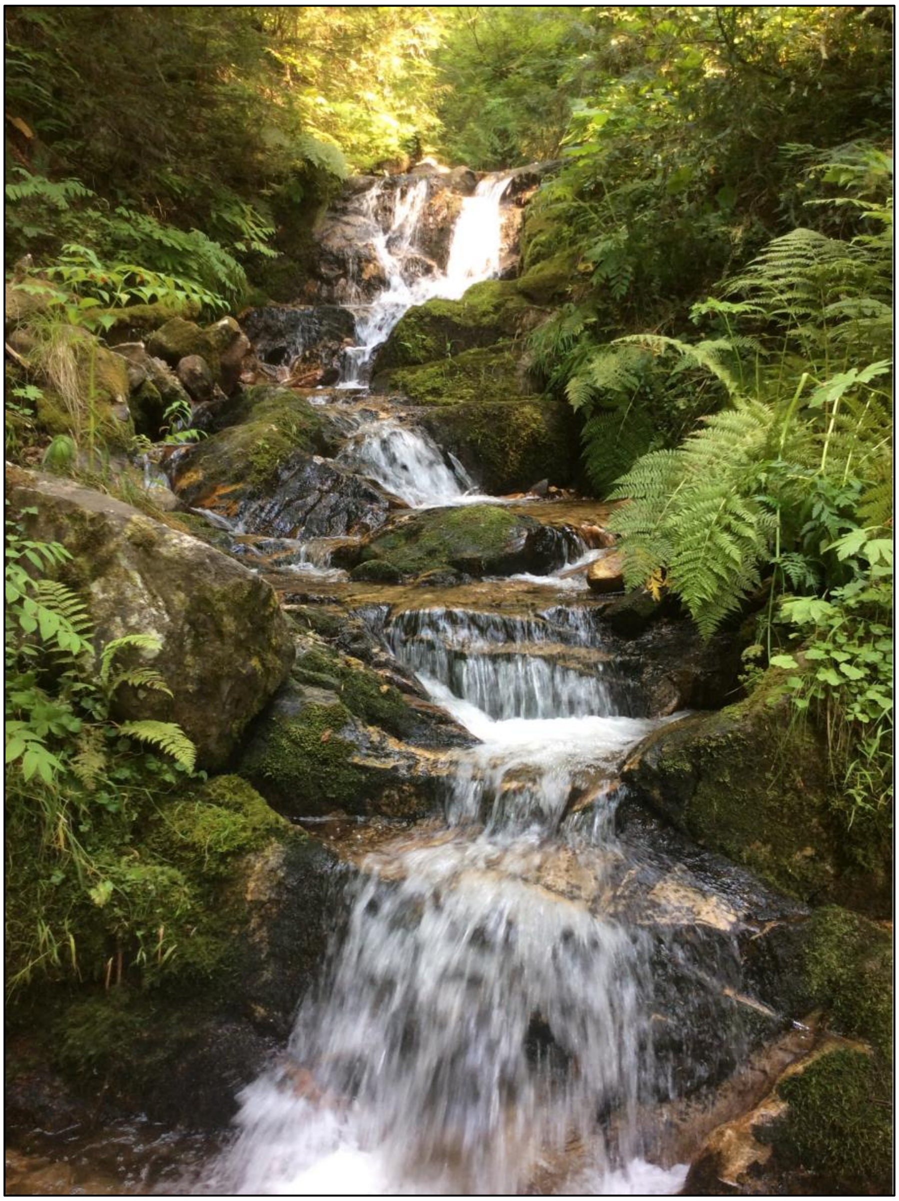

Photo E-9. Looking upstream at Potential Barrier 49.1, located in Reach 49 in a small tributary to Clear Creek known as “Tailed Frog Creek”.

Potential Barrier 49.2

This site is the second of two likely barriers within a 25 m high-gradient section of stream just upstream of the confluence with mainstem Clear Creek. This site consists of a 4.7 m steep bedrock cascade/falls with a 2.4 m vertical drop at the top. It is expected that this site, along with a similar feature just downstream, constitutes a total barrier to fish passage. This site is upstream of the documented upper distributions of anadromous salmonids and cutthroat trout.

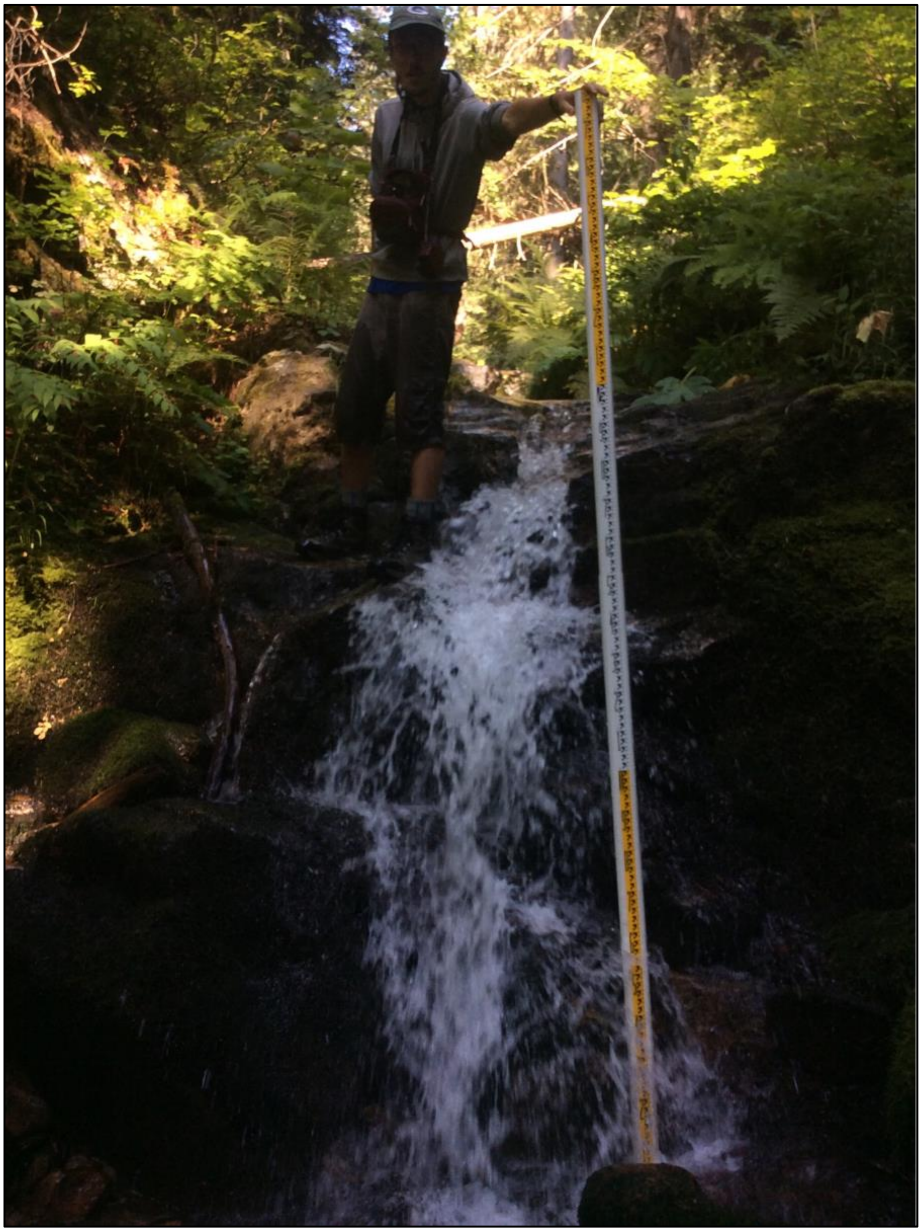

Photo E-10. Looking upstream at Potential Barrier 49.2, located in Reach 49 in a small tributary to Clear Creek known as "Tailed Frog Creek".

Potential Barrier 49.3

This site, a short cascade may present a seasonal, low-flow obstacle to fish passage due to a small and relatively shallow jump pool, a shallow crest, and lack of upstream resting areas. However, this site is likely passable by fish at moderate stream flows. This sites is upstream of two likely total barriers and above the documented upper distribution of cutthroat trout.

Photo E-11. Looking upstream at Potential Barrier 49.3, located in Reach 49 in a small tributary to Clear Creek known as “Tailed Frog Creek”.

WEST FORK CLEAR CREEK

Potential Barrier 12.1

This feature likely presents a passage barrier to anadromous fish across a wide range for flows due to the combination of jump height and jump distance from the pool. There is a potential passage route at higher flows on river right and it is possible that the feature backwaters enough to allow passage at higher flows. Chinook salmon were observed downstream, but not upstream of this site, suggesting it may prevent their passage. Presence of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-12. Looking upstream at Potential Barrier 12.1, located in Reach 12 of West Fork Clear Creek.

Potential Barrier 25.1

This site features a nearly vertical 1.5 m rock face with water sheeting over bedrock at the surveyed flows. Lack of a deep jumping pool in front likely creates a significant passage obstacle across most flows and is likely to be a total barrier at lower flows. Presence of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-13. Looking upstream at Potential Barrier 25.1, located in Reach 25 of West Fork Clear Creek.

Potential Barrier 27.1

This site likely presents a significant passage obstacle and could be a total barrier at some flows due to the presence of a log jam at the crest of a vertical drop over large boulders, as well as lack of jump pool depth. However, passage of anadromous fish could be possible at moderate to high flows due to backwatering associated with downstream boulders and logs. While still expected to present an obstacle, it appears that this site would be more readily passable if the log jam were not present at the jump crest. Presence of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-14. Looking upstream at Potential Barrier 27.1, located in Reach 27 of West Fork Clear Creek.

Potential Barrier 27.2

This complex feature consists of three adjacent drops. At the surveyed flows it may present a barrier to fish passage, but is unlikely to be a barrier at moderate to high flows due to a deep jump pool, relatively short jump heights and distances, multiple potential migration routes, and presence of large wood and boulders downstream that likely cause backwatering. Presence of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-15. Looking upstream at Potential Barrier 27.2, located in Reach 27 of West Fork Clear Creek.

Potential Barrier 27.3

This feature, just upstream of another potential passage obstacle, may present a seasonal barrier to passage of anadromous fish due to the combination of moderate jump height, long jump distance, and lack of jump pool depth. However, fish passage is likely possible at moderate to high flows due to backwatering associated with downstream logs and boulders, as well as a potential alternative migration routes on river right. Presence of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-16. Looking upstream at Potential Barrier 27.3, located in Reach 27 of West Fork Clear Creek.

LOST MULE CREEK

Potential Barrier 29.1

This site consists of a very steep, complex cascade that terminates in a vertical drop. It is assumed that this is a total barrier to anadromous and resident fish due to jump height and extent of high gradient channel upstream. An unknown trout was observed in jump pool below this feature and cutthroat trout were observed in Reach 28, just downstream. However, no fish were observed in the short distance surveyed upstream of the feature through the end of Reach 29.

Photo E-17. Looking upstream at Potential Barrier 29.1, located in Reach 29 of Lost Mule Creek, a small tributary to West Fork Clear Creek.

SOUTH FORK CLEAR CREEK

Potential Barrier 15.1

This site could present an obstacle and potential barrier to fish passage at low flows due to the long jump distance required to reach upstream resting locations and shallow water in the upstream channel. A split channel immediately upstream and series of rapids and small cascades could further impede passage at low stream flows. However, this site is most likely passable at moderate stream flows due to a relatively deep jump pool, multiple potential routes for passage, and small resting pockets within the upstream cascade and rapid. Presence of both *O. mykiss* and Chinook salmon upstream also indicate that this site is not a total barrier.

Photo E-18. Looking upstream at Potential Barrier 15.1, located in Reach 15 of South Fork Clear Creek.

Potential Barrier 15.2

This site could impede fish passage at low flows due to shallow jump pool and long horizontal jump distance required to reach upstream resting locations. However, deeper water at moderate to high flows likely facilitates passage both through the center of feature and at an alternative route along river right. Presence of both *O. mykiss* and Chinook salmon upstream also indicate that this site is not a total barrier.

Photo E-19. Looking upstream at Potential Barrier 15.2, located in Reach 15 of South Fork Clear Creek.

Potential Barrier 15.3

This site is the first of three potential passage barriers within a 100 m high-gradient section of Reach 15. At low stream flows this site likely presents an obstacle to fish passage due to the waterfall plunging onto boulders and relatively long jump distance required to reach upstream resting areas. However, with deeper water at higher flows, passage is expected to be possible through multiple routes. Presence of both *O. mykiss* and Chinook salmon upstream also indicate that this site is not a total barrier.

Photo E-20. Looking upstream at Potential Barrier 15.3, located in Reach 15 of South Fork Clear Creek.

Potential Barrier 15.4

This site is the second of three potential barriers within a 100 m high-gradient section of Reach 15. While it may impede fish passage at low stream flows, this site is not expected to be a barrier at moderate flows due to a deep jump pool and relatively short jump distance required to reach upstream resting areas. Presence of both *O. mykiss* and Chinook salmon upstream also indicate that this site is not a total barrier.

Photo E-21. Looking upstream at Potential Barrier 15.4, located in Reach 15 of South Fork Clear Creek.

Potential Barrier 15.5

This site is the third of three potential barriers within a 100 m high-gradient section of Reach 15. At the low flows surveyed, this site appears to have the potential to block upstream fish passage due to a long jump distance and relatively high jump height. However, at higher flows the site is expected to backwater due to downstream boulders and allow passage. An alternative high flow passage route may also exist on the right bank edge. Presence of both *O. mykiss* and Chinook salmon upstream further indicate that this site is not a total barrier.

Photo E-22. Looking upstream at Potential Barrier 15.5, located in Reach 15 of South Fork Clear Creek.

Potential Barrier 17.1

This feature appears to be a barrier to fish passage at lower flows due to lack of jump pool (plunge onto boulders) and presence of a cascade immediately below the drop. It is likely that the waterfall backwaters considerable at moderate to high flows due to presence of large boulders downstream, which may facilitate passage. However, juvenile chinook salmon were observed during snorkel surveys in a pool approximately 150 m downstream of this site, but were not observed again upstream of the site, suggesting it could be a total barrier to Chinook salmon migration. Presence of high densities of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

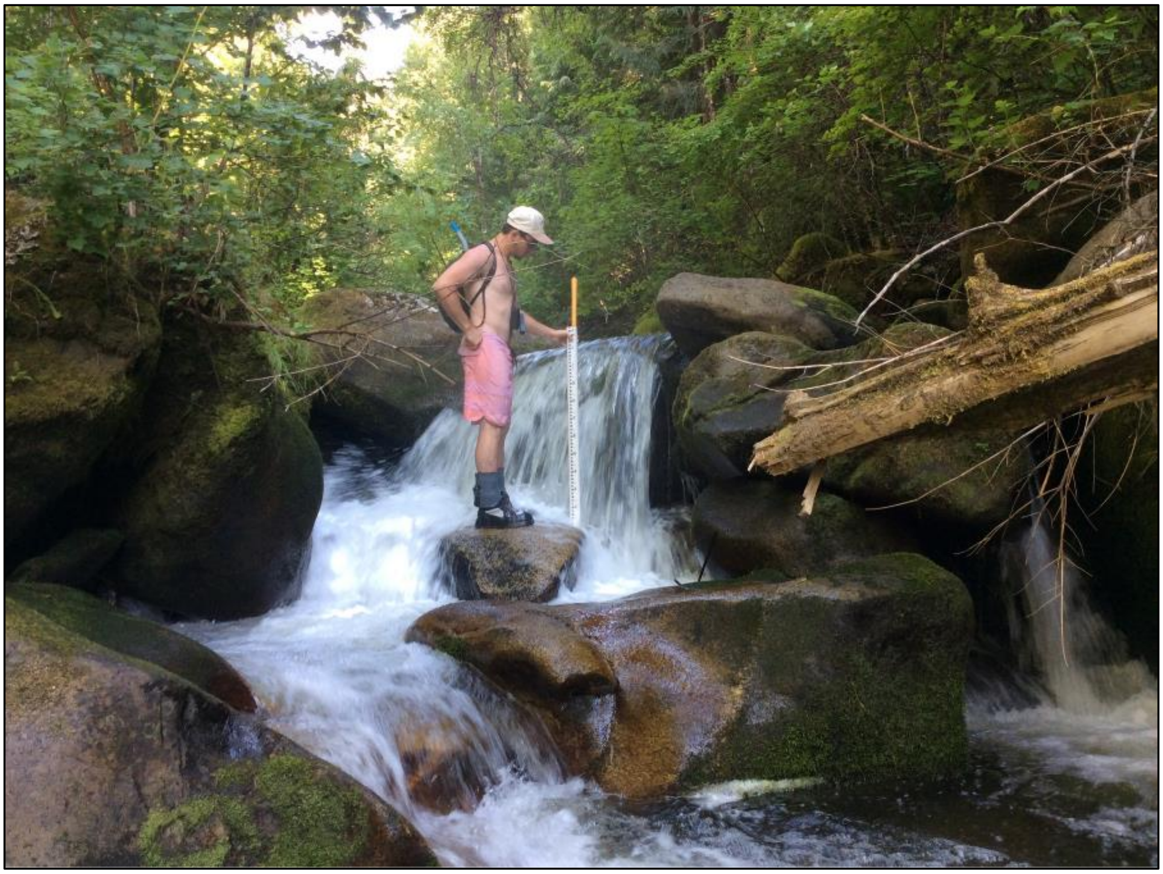

Photo E-23. Looking upstream at Potential Barrier 17.1, located in Reach 17 of South Fork Clear Creek.

Potential Barrier 19.1

This site is very unlikely to present a barrier to fish passage at moderate stream flows due to the short jump height and alternative passage routes on right bank; however, at low flows it may impeded fish passage due to a small wood jam near the crest and the long horizontal jump distance required to reach upstream resting areas. Presence of high densities of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-24. Looking upstream at Potential Barrier 19.1, located in Reach 19 of South Fork Clear Creek.

PINE KNOB CREEK

Potential Barrier 48.1

This feature consists of a very steep and shallow 11 m long cascade that ends in a 1.3 m drop. At low flows this feature is almost certainly a complete barrier to fish. At higher flows it is possible that fish can navigate through the feature, but the constrained nature of the channel indicates water velocities would likely approach the maximum swimming speed of steelhead. More extensive fish passage surveys and analysis would be required to determine this. Presence of *O. mykiss* upstream suggests either a population of resident rainbow trout exists, or steelhead can pass this features at some range of flows.

Photo E-25. Looking upstream at Potential Barrier 48.1, located in Reach 48 of Pine Knob Creek.

BROWNS SPRING CREEK

Potential Barrier 42.1

While likely a barrier to migration at low stream flows, this small falls is not expected to impede passage at moderate to higher flows due to a passage route on right bank and backwatering from downstream hydraulic control points. Only cutthroat trout were documented upstream of this feature, but in this case upper distribution of *O. mykiss* may be controlled by other factors.

Photo E-26. Looking upstream at Potential Barrier 42.1, located in Reach 42 of Browns Spring Creek.

Potential Barrier 44.1

At low stream flows, this small waterfall likely represents a barrier to anadromous fish due to a shallow jump pool, shallow crest, lack of an upstream resting pool, and no alternative passage routes. However, at moderate flows, the feature likely backwaters enough to allow passage. At high stream flows, high water velocities likely prevent passage at the site due to confined nature of the channel. Only cutthroat trout were documented upstream of this feature.

Photo E-27. Looking upstream at Potential Barrier 44.1, located in Reach 44 of Browns Spring Creek.

Potential Barrier 44.2

This feature consists of a long (18 m), steep, and shallow cascade with two significant bedrock chutes separated by a short lower gradient section. At low flows water sheets over bedrock in several places and is too shallow to allow fish passage. At moderate and higher flows water velocities are expected to be too high for passage and the necessary jump pools are not present below the drops. Due to being confined by steep hillslopes, no alternative high flow passage routes are available.

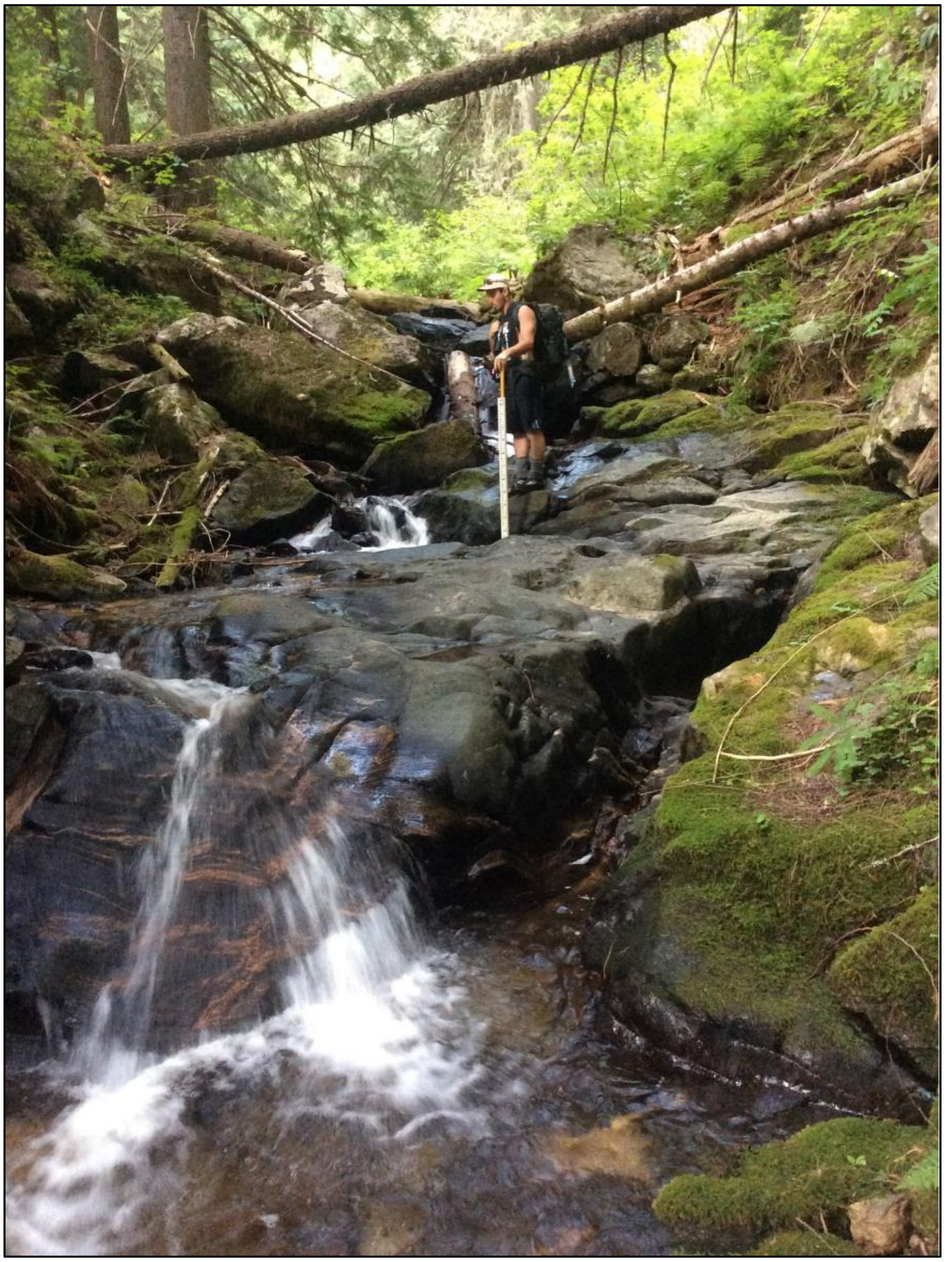

Photo E-28. Looking upstream at Potential Barrier 44.2, located in Reach 44 of Browns Spring Creek.

Appendix F

Review of Historical Fish and Habitat Information

A review of historical fish habitat and distribution surveys in Clear Creek was conducted in preparation for developing the monitoring strategy and preparing for fieldwork for this project. Key results from of this review are provided below.

Murphy and Metzger (1962)

Murphy and Metzger (1962) describe walking surveys of larger tributaries of the Clear Creek basin (along with many other rivers in Idaho). Regarding streams in the survey area for this investigation, they reported:

Clear Creek: "Riffle areas comprise 90 percent of the stream bottom and contain 14,891 square yards of suitable steelhead spawning area and 708 square yards of suitable salmon spawning area. Large and medium rubble covers 74 percent of the stream bottom, limiting the spawning value of the stream."

West Fork Clear Creek: "The stream channel gradient becomes steep beyond mile 0.3 and is considered impassable and of no value to migratory fish. The stream contains 50 square yards of suitable steelhead spawning area which comprises 2 percent of the total 3,000 square yards of stream bottom surveyed."

Middle Fork Clear Creek: "The stream flows through a narrow valley interrupted by small meadows containing excellent spawning gravels. Of the 40,321 square yards of stream bottom surveyed, riffle areas comprise 71 percent and contain 3,881 square yards of suitable steelhead spawning area."

South Fork Clear Creek: "There are numerous good resting pools. Riffle areas contain 1,928 square yards of suitable steelhead spawning area"

Pine Knob Creek: "One steelhead redd was observed at stream mile 0.9. Some 10,882 square yards of suitable steelhead spawning area are available in the stream. There are 187 square yards of suitable salmon spawning area in the 4.3 miles surveyed. Numerous good resting pools were observed."

They also note that much of the Clear Creek Mainstem was burned in 1931, resulting in small riparian trees, and high sediment loads.

Previous surveys summarized by Johnson (1984)

Other early surveys were not obtained by Stillwater Sciences, but were summarized in Johnson (1984) as follows:

- "Mallet (1974) estimated abundance of spawning gravels and fishing pressure by sports fishermen in Clear Creek, South Fork Clear Creek, Middle Fork Clear Creek, and Pine Knob Creek."

- "Martin (1976) conducted an ocular survey for the Idaho Department of Fish and Game and the Nez Perce National Forest on Clear Creek, South Fork Clear Creek, Middle Fork Clear Creek, and Pine Knob Creek. He described several stream substrate components on each creek. He also estimated available spawning habitat, benthos quality, and used angling techniques to determine the fish species present."

- "The U.S. Forest Service (1980) visually surveyed the Clear Creek drainage within the National Forest boundaries. Their survey described, by elevation: stream substrate characteristics, pool quality, channel stability, and barriers to anadromous fish migration."

- "The U.S. Fish and Wildlife Service (1981) conducted anadromous fish habitat and population surveys on the lower 12.5 km of Clear Creek. They also modeled the effects of improved flow regimes and riparian and instream enhancement on anadromous fish production in the lower reach."

Johnson (1984)

Johnson (1984) sampled seven 40–100 m sites in the Clear Creek basin that were within fish-bearing streams on National Forest lands where the USDA Forest Service defined reaches by survey priority (see Appendix A). These sites include: Clear Creek basin: Clear Creek at its confluence with South Fork Clear Creek, the headwaters of Clear Creek, South Fork Clear Creek near its confluence with Clear Creek, Pine Knob Creek, West Fork Clear Creek, and Middle Fork Clear Creek upstream of Solo Creek. The sampled sites in South Fork Clear Creek and Clear Creek near its confluence with South Fork Clear Creek were located within the high priority stream reaches, which were assessed during the current assessment (summer 2015 surveys). The West Fork Clear Creek and Pine Knob Creek sites were within the moderate priority stream reaches, and the Hoodoo Creek and Middle Fork Clear Creek sites were within the low priority stream reaches.

Johnson (1984) electrofished 40–100 m of stream at each site with a multi-pass methodology to estimate fish populations; data were collected on several habitat parameters; and water samples were collected at selected headwaters sites and analyzed for several chemical constituents. A summary of results from this survey are presented in Table F-1.

Table F-1. Summary of results of summer fish habitat and population surveys conducted in selected Clear Creek basin stream by Johnson (1984).

Survey Stream	Clear Creek[1]	Upper Clear Creek	West Fork. Clear Creek	Hoodoo Creek	South Fork Clear Creek[1]	Middle Fork Clear Creek	Pine Knob Creek
Stream kilometer (mi)	18.1 (11.3)	32.0 (19.9)	5.4 (3.4)	1.7 (1.1)	0.1 (0.06)	6.4 (4.0)	4.7 (2.9)
Summer water temperature(°C)	9.1	11.1	12.2	11.7	3.9	11.7	12.2
Summer streamflow (cfs)	14.83	0.71	1.06	1.41	18.01	1.06	0.35
Water velocity (ft/sec)	1.31	0.63	0.60	0.57	1.52	0.49	0.16
Mean width (m)	6.0	1.9	2.0	3.0	5.2	3.5	2.8
Mean depth (m)	0.57	0.19	0.30	0.23	0.71	0.20	0.25
Instream cover (%)	4.0	3.0	4.8	3.1	8.4	1.7	2.9
Eroding banks (%)	10	40	30	50	60	25	20
Cobble Embeddedness (%)	0	25	50	75	75	25	50

Survey Stream	Clear Creek[1]	Upper Clear Creek	West Fork. Clear Creek	Hoodoo Creek	South Fork Clear Creek[1]	Middle Fork Clear Creek	Pine Knob Creek
Major substrate type	large and small rubble	large and small rubble	sand	sand	sand	large and small rubble	sand
Pool:Riffle Ratio	25:75	25:75	33:66	25:75	25:75	17:83	20:80
Periphyton Coverage	20	0	10	0	10	0	0
Age 0+ O. mykiss density (fish/ft^2)	1.94	0	0	0	0.03	0.54	0
Age 0+ O. mykiss standing crop (pounds/acre)	30.83	0	0	0	1.04	13.95	0
Age 1+ O. mykiss density (fish/ft2)	1.40	0	0	0	0.11	0.43	0
Age 1+ O. mykiss standing crop (pounds/acre)	157.11	0	0	0	8.23	53.61	0
Age 0+ cutthroat density (fish/ft^2)	0	0	present	0	0	0	present
Age 0+ cutthroat standing crop (pounds/acre)	0	0	present	0	0	0	present
Age 1+ cutthroat density (fish/ft2)	0.03	8.61	3.55	0	0	0	5.70
Age 1+ O. cutthroat standing crop (pounds/acre)	2.56	353.83	283.06	0	0	0	387.33
Fish species collected	*O. mykiss*, cutthroat trout, Paiute sculpin	cutthroat trout	cutthroat trout	none	*O. mykiss*, Paiute sculpin	*O. mykiss*	cutthroat trout

Johnson (1984) identified the following "problems" on each of the surveyed creeks:

- West Fork Clear Creek: "Migratory barriers; low summer flow; unstable stream course; lack of instream cover; shallow mean depth; lack of good pool habitat; and sedimentation." A natural barrier at RM 0.31 prevents upstream passage.
- Hoodoo Creek: "Migratory barriers; low summer flow; unstable stream course; lack of instream cover; shallow mean depth; lack of good pool habitat; and sedimentation." The barrier on West Fork Clear Creek, and a falls at Hoodoo Creek RM 0.62 prevent passage up Hoodoo Creek.
- South Fork Clear Creek: "Sedimentation; lack of instream cover; lack of pools and occasional debris jams." There was a high sediment load due to upstream logging.
- Middle Fork Clear Creek: "Low summer stream flow; lack of instream cover; shallow mean depth; lack of pool habitat; and migratory barriers."
- Pine Knob Creek: High sedimentation and gasket effect [embeddedness]; low summer flow; lack of instream cover; shallow depth; and lack of pool habitat.

Paradis et al. (1988)

Paradis et al. (1988) conducted a much more extensive stream habitat survey and collected fish by angling to inform fish distribution. A total of 17.5 miles of the basin were surveyed, including portions of Clear Creek, South Fork Clear Creek, West Fork Clear Creek, Hoodoo Creek, West Branch Creek, Lost Mule Creek, and Kay Creek. Of these, Clear Creek, South Fork Clear Creek, and the lower portions of West Fork Clear Creek and Lost Mule Creek are high priority reaches for the 2015 assessment. Kay Creek and the upper reaches of South Fork Clear Creek are moderate priority, the lower reaches of Hoodoo Creek and West Branch Creek are lowest priority.

Notable findings from Paradis et al. (1988) include:

- Just two miles of the mainstem of Clear Creek was surveyed, from the Forest Service boundary upstream. The reason for not surveying past the two mile point is likely because a series of features considered barriers by the authors was encountered at the point where the survey terminated:

  "…. The first barrier is a complete barrier to Chinook. The bedrock falls and cascades are too high and have inadequate plunge and landing pools for adult Chinook migration. This barrier exists for 150 meters, and the gradient is approximately 15%. Steelhead are able to negotiate the falls because of the higher flows during the time they migrate. There is, however, another barrier at the upstream end of this 150 meter stretch which is most likely impassable to all fish. It consists of large conifer debris. The barrier is 20 meters wide and the shortest vertical passage is 3.0 meters and very narrow (0.8 meters wide). At this point passage is improbable. However, numerous rainbow trout, possibly juvenile steelhead, were caught above the barrier….Very high densities of juvenile steelhead were found between the two barriers. This may indicate that steelhead have been migrating to the upper barrier and spawning out since they could go no further."

- There was a lack of canopy cover in mainstem Clear Creek due to the 1931 fire, and embeddedness was high. The creek was described as having good heterogeneity of pool, riffle, run and pocket water, with a pool:riffle ratio of 52:48.

- Approximately 8.5 miles of South Fork Clear Creek were surveyed. One third of the surveyed area had "adequate cover" which had been reduced by the 1931 fire. Substrate was large boulders and large rubble, bedrock and sand. Sedimentation of pools and cobble embeddedness was high. A series of waterfalls considered to be a total barrier to fish was present on South Fork Clear Creek at approximate RM 1.1 (note that GIS metadata provided by USDA Forest Service, indicate this feature was blasted in 1991 to provide fish passage).

- In South Fork Clear Creek rainbow trout/steelhead predominate in the lower reaches, while cutthroat density increases in the upper reaches. Cutthroat trout become the dominant species upstream of the Kay Creek confluence.

- A total of 3,700 meters (2.3 miles) of West Fork Clear Creek were surveyed, but the surveyed reaches were discontinuous. Numerous fish passage barriers were noted. The report states that, "these barriers, along with the lack of spawning and winter rearing habitat, have rendered the stream almost useless to anadromous fish."

- Two discontinuous sections of Hoodoo Creek were surveyed. The gradient of the reach below an impassable falls was 8%. Hoodoo Creek was described as having good potential debris, and a good variety of habitat, with a pool riffle ratio of 41:59. Sedimentation was high, and Hoodoo Creek was not accessible to anadromous salmonids due to the barrier on West Fork Clear Creek. A good population of native cutthroat was reported.

- A total of 180 of 700 meters (0.43 miles) of Lost Mule Creek were surveyed. Gradient was high at 8%. Sediment level was described as very high and the stream was very small with little discharge.

Table F-2 summarizes some of the findings from Paradis et al. (1988):

Table F-2. Fish habitat data presented in Paradis et al. (1988).

Stream	% embeddedness pool/riffle/overall	Pool:Riffle	Spawning habitat (m^2/km)		
			Resident	Steelhead	Chinook
Clear Cr	49/29/38	52:48	5.2	4.9	0.6
South Fork Clear Cr	71/38/51	48:52	10.4	7.7	0.5
West Fork Clear Cr	70/42/57	53:47	37.8	12.4	2.4
Kay Cr	48/20/34	41:59	83.0	6.7	0.0
Lost Mule Cr	80/65/71	42:68	11.4	0.0	0.0
W. Branch Cr	78/39/55	44:56	27.9	11.8	0.0
Hoodoo Cr[1]	65/38/48	41:59	57	71	2

[1] Spawning gravel for Hoodoo Creek is total reported, not total/km, because the total length surveyed was not reported.

Overall, these historical assessments suggested that the primary factors limiting fish in the Clear Creek basin were fine sediment, a lack of spawning gravel, lack of pool habitat, and barriers.